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INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

13th SESSION (PARIS, 1937).

QUESTION VIII.

Application of rational organisation (planning) to the transport of goods,

especially in connection with :

1. the functions and internal working of shunting yards;
2. the provision of inter-yard connections;
3. the estimation of the probable traffic to be dealt with, and the provision of the trains required;
4. the information to be given to consignees;
5. the acceleration of the turn-round of empty stock;
6. the use of containers and rail-road wagons.

REPORT

(Germany, Austria, Bulgaria, Denmark, Finland, Greece, Hungary, Norway, Poland, Rumania, Sweden, Czechoslovakia, Turkey and Jugoslavia)

by Dr. Ing. A. BAUMANN,
Reichsbahndirektor, Deutsche Reichsbahn.

CONTENTS :

I. Organisation of the work in shunting yards.
  A. Planning the work of splitting up the trains.
  B. Working method for marshalling the trains.
II. Train service between marshalling yards.
III. Estimation of the probable traffic to be dealt with, and provision of the trains required.
IV. Advice to consignees.
V. The acceleration of the turn-round of empty stock.
VI. The use of containers and « rail-road » wagons.

The goods traffic is the financial keystone of nearly all railway undertakings. Consequently special attention has to be devoted to this branch of the working, the more so that competition of other means of transport, especially road motor transport, increases.

The road vehicle offers some advantages to the individual consignor, and takes comparatively little time to complete the whole journey, so that in some respects it has the advantage over the railway which has to work the traffic by train. So far, the loss of time in shunting and marshalling the wagons on the one hand and in delivering the goods to destination on the other cannot be recovered except on very long runs thanks to the higher rail speeds.

Shortening the time spent, within the limits or even thanks to the improvement of the economic position, is one of the most important problems connected with railway goods traffic. The examination of Question VIII, based on the replies received from the various Administrations consulted, will provide a valuable contribution to the solution of this interesting problem.

I. — Organisation of work in shunting yards.

A. *Planning the work of splitting up the trains.*

Trains are split up on much the same methods on all the railways covered by our report, at any rate on those owning shunting yards, and this is more or less due to operating requirements.

There is, however, no indication that on any of the railways the shunting operations take place in a regular manner, for example on characteristically industrial lines. If an attempt be made to obtain such a result, the first difficulty encountered is that the work varies with the arrival and departure times. Moreover, any reduction in the transport time means the wagons remaining in the station the shortest possible time, trains on arrival must be split up and the new trains marshalled in the minimum time.

The usual consequence is that the operations follow one another in an order which suits the general organisation of the service. Only the Reichsbahn reports it is methodically organising the shunting service in all yards involving over 24 locomotive -- hours daily. Each such yard draws up a shunting list which shows, on the lines of the attached model for the 24 hours of a normal day :

(*a*) the trains passing through the yard, in the form of a time graph;

(*b*) the trains to be shunted in the yard, with the operations involved, in the form of tables;

(*c*) the receiving and marshalling sidings and the places where the working is very concentrated (humps, frequently used points and crossings, etc.) are shown by graphs, in bands or columns;

(*d*) a diagram of the work done by the locomotives and sets of men used. The times experience shows necessary, with their individual values (care being taken not to use the average values of the whole of the trains) are marked on parts (*c*) and (*d*) of the harmonograph.

By means of this plan, represented by a simple model, the quantity of work to be done, the occupation of the tracks, and the staff required are readily determined. The times at which additional work is possible without overloading the working and without additional staff are revealed; inversely it shows how and at what hours, by changing the train timings or the order of carrying out certain operations, the work in the yard can be lightened, and the locomotives and staff be employed more effectively and more economically. The train workings and enginemen's turns are drawn up in accordance with this plan. All departures from the plan which are so frequent and so numerous as to suggest discordance between it and practice, are noted and

used for the gradual improvement of the working method.

Nearly every shunting yard on the *Reichsbahn* is required to get out this shunting plan and to continue it from one set of timings to the next, and to improve it in accordance with the results obtained in practice. In each station, the use made of the sidings and labour is represented in the model laid down, so as to supply all the information needed to ascertain that the work is carried out regularly and *according to plan*. The different operations, sets of men and locomotives (1) separated by destination are planned, entered and checked and the operating methods are amended as experience dictates.

The following points concerning the working methods should be kept in mind as applying to the railways consulted :

1. On the arrival of the train, the guard hands in with the wagon waybills a list showing how the train is made up, by loading and destination stations, for use in checking the incoming wagons.

2. The marking off of the cuts by destination, i.e. to ensure they are shunted unto the marshalling sidings corresponding to their ultimate destination, is done usually at the same time as the arrivals are checked, but mainly by special staff.

Some railways (*Deutsche Reichsbahn, Austrian Federal, Polish State* and in some cases the *Czechoslovak State Rys.*) prepare shunting lists which indicate the cuts with the number of wagons in each and their destination siding in the order in which they follow each other down the hump. Any special points about each cut, such as loads to be shunted with care or requiring brakesmen, are marked on the list. Moreover, in large yards, and in all yards on the *Reischbahn*, the sidings column of the list is subdivided to show the sidings covered by the different men handling the slipper brakes. Copies of the shunting lists are distributed to the employee who supervises the shunting, the men handling the skids, the signalmen and men working the track brakes, and on the *Reichsbahn* to the driver of the shunting engine pushing the train over the hump. In this way the men handling the slipper brakes know in advance the sidings unto which the wagons will be shunted and their foreman, by making suitable arrangements, can liberate any men not fully employed and use them where they are needed to brake cuts being shunted. Likewise, the signalmen and track brakesmen know from the list what has to be done before the wagons come down, so that they can make the necessary arrangements, and if need be, alter them during shunting, as for example when certain sidings already hold a large number of wagons. The lists help the drivers to regulate the shunting speed, especially when there is a great difference between the long and short cuts. These shunting lists can be considered the best method of communicating with the staff, and as being essential in busy yards. Their successful use depends on their being reproduced in large enough numbers, for which purpose special typewriters are used in the large yards. The *Reichsbahn* uses these special machines and makes up to 11 copies at a time from the statement prepared on the arrival of the train.

When the shunting lists are not made out, the number of the siding is chalked on the first wagon of each cut (*Hungarian State* and in some cases *Czechoslovak State*), or shunting cards are attached to the wagons (*Jugoslav State*).

3. On nearly all the railways, the wagons are inspected as soon as they are

(1) In this way, results are obtained similar to those given graphically in Mr. Colle's report, page 1027 of the October 1936 number of this *Bulletin*.

in position in the reception sidings, so as to be able to cut out all defective wagons whilst splitting up the train, and thereby speed up the repairs or transhipment. On the *Deutsche Reichsbahn,* however, the wagons are not examined on arrival in the case of small yards, as the defects found in addition to those reported during the journey are generally few in number, but instead, the wagons are inspected on the outgoing roads so as to discover any damage to wagons (extant on arrival or sustained during shunting in the yard).

4. Moreover, the practice on all railways is to prepare the wagons to be passed over the hump on the reception sidings by uncoupling the main draw gear and the brake pipes, and, when used, the safety chains, between the cuts of wagons. The brake is also released. Previously, the wagons must be marked off with the siding number, as described under 2, before splitting up the train.

5. The time needed to get a train ready for shunting is generally 45 to 60 minutes.

6. The shunting properly speaking in marshalling yards is done over a hump, in most cases with a locomotive ; in exceptional cases by gravity on sidings laid on a gradient. The number of locomotives required depends on the layout of the yard and the rate at which the trains succeed one another. When the trains arrive directly at the foot of the hump, the locomotive takes at least 10 minutes from starting to deal with the first train to starting on the second. If the trains have to be worked from a reception siding to the shunting siding, the time required, including shunting, can be as much as 30 minutes per train, according to the replies received to the questionnaire.

The speed down the hump depends on many factors, such as the gradient and height of the hump, arrangement of the points, atmospheric conditions, type of wagon and load, number of wagons in the cuts, etc., and on most railways is a walking pace. The *Czechoslovak State Rys.* calculate the speed as 0.6 m. (2′) per second, and the *Reichsbahn* as 0.5 m. to 1 m. (1.65′ to 3.3′) per second.

7. Most of the railways control the speed down the gradient by three methods :

(*a*) Track brakes, some of a very simple type and others of a highly developed pattern, usually located at the bottom of the hump;

(*b*) Slipper brakes placed on the sorting sidings to stop the wagons close to those already in the sidings;

(*c*) Brakesmen riding with the wagons, especially those which on account of their loads must not be rough-shunted, or long cuts (of more than 12 wheels for example).

The ordinary track brakes are each operated by one man, according to the replies of the railways ; the improved brakes, remote-controlled, are allotted in pairs to one man.

The men placing the slipper brakes look after 2 to 4 tracks. The usual method is to station the men in echelon across the sidings. The intermediate braking at a second line used in some countries, according to the technical press, is not the practice on any of the railways consulted. For safety reasons, the men place two slipper brakes on the rails, one behind the other, and withdraw the second when the first has done its work. In ordinary practice the men handling the slipper brakes help one another and also act as brakesmen with such wagons as those described under (*c*).

Operation of the track brakes and the distribution of the men using the slipper brakes and the brakesmen are generally based on the shunting list (see above under 2, paragraph 2).

7. As shunting lists are got out in almost all yards, the signalmen dealing with the shunting find them of assistance in carrying out their work. If the lists are distributed in good time the preparatory work can be started, and if any changes are required in the list, joint action can be taken.

B. *Method of marshalling the trains.*

The work involved in marshalling the trains is decided by :

(*a*) the task imposed on each train of serving certain stations as listed in the regulations on marshalling goods trains or other similar instructions;

(*b*) the objective consisting of obtaining on important services the quick turnround of the wagons; to achieve this, transferring wagons from arriving trains to suitable departing trains is laid down once and for all in the wagon exchange regulations or prescribed in each particular case;

(*c*) the timetables which necessitate the trains being ready in time.

Just as when breaking up a train, a harmonograph cannot be drawn up for this case. Nonetheless nearly all the Railways have organised the train marshalling work on uniform lines. The notes under A on the *Reichsbahn* splitting-up plans also apply *mutatis mutandis* to the marshalling thereof. The following points should be noted :

1. If the train is to be marshalled properly, the number and in certain circumstances the weight of the wagons to make up a given train must be known. Many Railways use the waybills for this purpose, sorting them by directions and sometimes by trains as well. This method shows the wagons on the corresponding marshalling sidings. Other Railways, such as the *Polish State, Czechoslovak State, Austrian Federal* and *Reichsbahn* control, at least in some of their yards, the number and weight of the wagons in the different sorting sidings, by continually recording the increases and decreases in the stock present.

2. The number of wagons to be dealt with must be known if the marshalling of the train is to be carried out methodically. If the number is large, optional trains can be run (see Chapter II); if there are few wagons coming in, booked trains may have to be cancelled.

3. The railways have not given any information differing from that reported in the technical press about train marshalling. This work consists in coupling together into a train several cuts of wagons marshalled previous to the shunting, or to re-marshall the wagons accumulated on a siding, allocated to a number of destinations. Train marshalling work, unlike splitting up, can be carried out in connection with several trains at one time. Nonetheless the different trains should be dealt with in sequence order, so as to use the labour to the best advantage. According to the amount of remarshalling necessary, the actual time required to make up the trains and move them ready on the departure line varies between 60 and 80 minutes.

4. A number of operations (checking the couplings, testing the brakes, recording the train composition, examination of the stock, handing over the waybills, etc.) requiring 40 to 60 minutes, must be completed between the time the train is marshalled and that of its departure.

5. To sum up, under normal operating conditions the time taken to deal with a wagon averages 3 hours provided there is no delay in the shunting and marshalling sidings through other wagons arriving later. The waiting time depends on the number of trains in the particular service; when there are two trains a day, spaced about 12 hours, it averages 12 : 2 = 6 hours; with four trains following one another at 6-hour intervals, it is only

6 : 2 = 3 hours. Consequently in order to speed up the goods traffic, especially when traffic is declining, some Railways have combined the trains made up of only one or two lots of wagons which run at long intervals with others in the same direction. Little of the time saved is lost if in the shunting yards served beyond, the lots of wagons ready marshalled for the remainder of the route served are kept apart from the ordinary working, and if each rake of wagons shunted off the train is replaced by another rake ready to leave.

II. — Train service between marshalling yards.

A distinction is made as a general rule between long-distance and short-distance goods trains. The latter serve all or most of the stations between the shunting yards; part of the former stop at the important or large junctions between the shunting yards, in order to detach or pick up wagons.

Another subdivision generally used is between regular and optional trains.

1. The number, type and running times of the regular trains are fixed before each revision of the working timetables, according to estimated (probable) traffic, the information received from connecting trains, and are printed in the working timetables and in the train-marshalling regulations. According to the size of the railway system, the departure times from the dispatching station, as far as possible late in the evening, and the time of arrival at the receiving station, preferrably early in the morning, are settled at the same time.

The *Jugoslav State Rys.* incorporate the necessary trains in the day service they organise so as to ensure the trains arriving at and leaving the shunting yards at fairly regular intervals, so that the working of these yards may be as constant as possible.

On the *Czechoslovak State Rys.* the number of booked trains is based on those run on the slackest week day in order to avoid having to cancel any regular train.

For the same reason the *Reichsbahn* includes amongst its booked trains certain trains known as «Stammzüge» which provide over long distances continuous connections between goods trains, and cannot be cancelled without the long-distance goods traffic being affected. These trains, when not required, can be cancelled only by the divisional headquarters and not by the stations, except in special cases.

2. Provision is made in nearly all working timetables for optional trains to convey wagons that cannot be forwarded by the booked trains. Special trains run at other than booked times, usually arranged for by telegram as needed, are exceptional. On the *Reichsbahn* the make-up of special trains is laid down when getting out the timetables; on the *Swedish State* this is the practice in the case of the trains most frequently run.

3. As regards speed, weight and composition, the optional trains are treated like the booked trains. The information supplied on this subject in answer to the questionnaire is given in the table hereafter.

4. The decision to run optional trains depends on the number of wagons in the station, which cannot be worked forward by the booked trains and of those due to arrive. The *Reichsbahn, Danish State, Polish State, Swedish State, Czechoslovak State* and *Jugoslav State Rys.* run optional trains as soon as they are found necessary, leaving in from 2 to 12 hours. Some Railways consider

Railway.	Maximum speed km./h.	Maximum number of axles.	Remarks.
Reischbahn	65 70 to 90	120 150 90	In special cases.
Austrian Federal	60	200	...
Danish State	45	120 140 for lighter trains.	In special cases.
Hungarian State	50	150	...
Polish State	Varies on each line according to the gross load and conditions on the line.		
Swedish State	60 70	120 80	Certain special trains.
Czekoslovak State	50 60 (seasonal trains)	...	The load depends on the line and tractive power of the locomotive.

3 hours the minimum time required to provide locomotives. On the other hand, the *Austrian Federal* and *Hungarian State Rys.* announce several times a day the optionals to be run at given times; and isolated specials are only run at intermediate times in special urgent cases.

5. On most railways a minimum load is laid down for the optional trains. On some railways this load must equal to or be a certain proportion of that of the booked trains; other railways require a minimum fixed load of say 200 to 300 tons. In many cases the running of optionals and their load are specially controlled.

Thus, on the *Reichsbahn* the stations take the initiative in the way of running optional trains in urgent cases only. In ordinary cases this is a matter for divisional or district headquarters who, on receipt of a demand for an optional train arrange for the locomotive and men and its use on a return optional. The load of the optional trains is controlled like that of the more important booked trains by the weekly train load statements, which give the information for each day separately. This practice is also followed on the *Swedish State, Austrian Federal, Danish State, Hungarian State,* and *Jugoslav State Rys.*

6. The number of optional trains depends on the way the number of booked trains is determined, and on the traffic fluctuations on the different week days. Some railways give the ratio of optional

to booked trains according to the mileage, as for example :

Reichsbahn : 6 to 10 % ;

Austrian Federal : varies from line to line, and is high at the week end;

Danish State : 20 %;

Hungarian State : low in normal times; up to 100 % during the busy season ;

Swedish State : 3 % on the average;

Czechoslovak State : nearly 100 % on the main lines; low elsewhere;

Jugoslav State : 10 %.

These extraordinary variations can only be understood by remembering the different practice followed in making required optional into booked trains.

All the railways decide the question after noting during a more or less long period the days optional trains are used, and their loads. Some railways make an optional into a booked train at the end of a fortnight or a month during which the optional train has been run from 2 to 3 days to 5 to 6 days, whilst others make the change when re-issuing the timetables or, like the *Jugoslav State Rys.*, only very rarely.

* * *

III. — Estimation of the probable traffic to be dealt with, and provision of the trains required.

It is extremely helpful, as regards the regularity of the service, to know as early as possible the traffic expected to arrive. A distinction has to be made between :

(*a*) traffic not loaded on rail, the consignor of which has to give notice in advance;

(*b*) traffic already en route which has to be reported from station to station.

1. The question of knowing in time the traffic to be provided for, when it exceeds the normal, has not been solved satisfactorily on any of the railways consulted. Provision can be made for certain traffic, such as that arising in the harvest season, although not always as regards destination. The previsions are based on information collected from the producers and consumers or from the public authorities. In the case of seaborne traffic, as enquiries have to be made for freightage, the preparatory work can be done about a week before the goods have to be carried. This also applies to fixed date consignments of industrialists.

If preliminary notices of this kind also affect neighbouring railways, they are forwarded, but only in certain cases.

No railway possesses any general regulations on previous notification of new traffic nor of isolated loads; there is no suggestion of drawing them up. In most cases statistics based on previous years have to be used.

2. As regards traffic already handed over to the railway, the notification is given nearly everywhere in one of two ways : according to the first, the advice notes showing the tonnage and destinations of the consignments are sent from the dispatching station to the first shunting yard and subsequently from one shunting yard to the next until the destination station is reached; the second method is to send them from the dispatching station to a central office — for example, on the *Rumanian State Rys.*, to the traffic controller — which in turn advises the shunting yards en route as well as the destination station.

3. Another basis in general use for estimating the traffic to be worked is the demand for empty wagons. According to the replies received from several Railways, experience in the long run teaches just what local or general steps have to

be taken as soon as the demands for empty wagons reach or exceed a certain figure within a more or less wide radius. On most railways the allocation of empty wagons is dealt with from a central office, so that the steps to be taken to deal with traffic fluctuations can be taken rapidly and effectively by agreement between the operating services.

4. On the majority of railways it is only in periods of very heavy traffic (heavy demands for wagons) that the consignors are required to give some preliminary notice when the loading will be completed. The stations, however, keep themselves informed as to the position so as to get the wagons away as soon as possible. The *Austrian Federal Rys.* and the *Jugoslav State Rys.*, as a general rule, or at least for perishable goods, put up in the shunting yards notices of the loads not completed with the date and time they probably will be, and take this information into account when calculating the weight of the train in question; as much as 24 hours can be saved in this way on such consignments.

* * *

IV. — Advice given to consignees.

The interests of all railways require that all goods should be off-loaded as soon as possible on arrival, so that the wagons are available for re-loading and the sidings are not occupied too long. In the case of livestock or perishable goods claims can be avoided by off-loading the wagons promptly.

For the same reasons, and quite apart from the stipulations in the tariffs or the operating regulations, most of the railways lay down that the consignee be advised of the arrival of his goods; different methods of notification are used for complete wagon loads of any kind and for cattle.

A. *Complete wagon loads.*

1. Complete loads as a rule are announced to the consignee by the arrival station. The method of advice varies according to the circumstances and according to the size of the station and the arrangements made with the consignee.

2. Telephone or telegraph messages, and letters sent by post or by messenger are used to convey the advice. The cost is debited to the consignee; unless special arrangements are made to do so, telegrams are not sent owing to their greater cost, except in the case of important loads or consignments of great value, or which are perishable or dangerous.

3. If the telephone is not available the advice is sent as a rule by postcard. Some railways (*Rumanian State*, and in the case of certain goods the *Swedish State*) use advice notes generally attached to the waybill, filled in before dispatch by the consignor, which are detached from the waybill at the receiving station and sent to the consignee. Similar advice notes filled in when the goods are dispatched but not attached to the consignment notes are used on the *Hungarian State* and on two *Swedish private Railways*. The *Austrian Federal Rys.* advise the consignee by sending a copy of the waybill, which method the *Czechoslovak State Rys.* are intending to introduce.

4. The advice note in every case gives the time within which the goods must be cleared; once this period has expired, demurrage costs are charged.

5. The practice of the dispatching station sending the advice note is not followed by any of the railways consulted. The arrival is notified by the receiving station within one to three hours after the wagon has been put into position on the off-loading siding. Wagons arriving between 6 p.m. and the opening of the yard the next day, as well as wagons

arriving on Sundays and holidays, are only notified the morning of the following working day except in cases of urgency.

6. With the exception of *Finland, Rumania* and *Jugoslavia,* the usual practice is for the consignor to advise the consignee when the consignment has been sent off. This information does not make it possible, except for short distances, for the consignee to determine when the goods will arrive, except in the case of regular consignments when he knows by experience the time the journey takes, or when the loads are worked to a definite plan as in the case of important goods on the *Reichsbahn* and *Czechoslovak State,* drawn up in agreement with the consignor. In this latter case, the advice to be given to the consignee by the receiving station is unnecessary; moreover, none of the railways consulted consider that the advice of the dispatch of the goods makes it unnecessary to advise the consignee of their arrival.

B. *Conveyance of livestock.*

1. In the case of livestock, all the railways consulted do not advise the consignee when the animals are accompanied; the man travelling with the wagons is considered as authorised to take delivery and the consignment is reckoned as having been delivered as soon as it has been put into position for offloading.

2. As regards consignments not accompanied, the consignee is advised as soon as possible, within two hours of arrival at most, even outside working hours. Methods similar to those mentioned in A2 and 3 are used; telegrams and express letters are used if found much quicker. On the *Swedish State Rys.* preparations are made for giving this advice by requiring one of the stations along the route to advise the destination station that such consignments are on their way.

3. The Reichsbahn gives a preliminary notification in the case of live fish, shellfish, etc. In the interest of the railway, consignments of this kind are notified by telegraph from the dispatching station to the receiving station. or if needs be by one shunting yard to the next. If the consignor requests it, the name and address of the consignee are given in the preliminary advice and the consignee is advised by telephone, telegram or messenger, and at the expense of the consignor of the probable time of arrival of the train. There is no guarantee given that the time of arrival advised will be kept to, although usually there will not be much variation. Consequently in addition to the preliminary advice the consignee is again advised in the usual way (see A2 and 3) of the actual arrival of the consignment, unless he is already present to take delivery.

C. *Ascertaining the times of arrival of goods by the consignee.*

Some railways show all the train services, or at least the most important ones in the goods train timetables, which are sometimes reserved, however, as in *Hungary* and *Rumania,* for domestic use only. The most complete timetable of this kind is that published by the *Deutsche Reichsbahn,* which gives the timings of the regular goods trains running daily or on certain days, as well as the passenger trains on which cattle, as well as parcels, and certain goods are carried without restriction; it also gives the route followed on long distances, and the transfer of wagons from one train to another at junctions, so that it is possible to ascertain the time taken for the journey, even in the case of long journeys. In many through services, the most useful connections are given in special chapters. The use of these timetables by the public is rather complicated, though they are

indispensable for domestic use. Therefore, the practice of advising the consignee of the actual arrival of goods cannot, generally speaking, be replaced by reference to the goods timetables.

D. *Consequences of the advice given to the consignee.*

Several of the railways consulted report that they send their consignment notes in advance by the fastest passenger trains, either regularly (*Swedish State* and *Private Railways, Turkish State*) or in certain cases (*Austrian Federal, Czechoslovak State*). As some railways point out, the sole object of doing this is to speed up the checking of the invoices and the payment of the charges, but not to give the consignee earlier notice; in the case of documents sent on in advance, the consignee is only advised when the goods have actually arrived.

Consequently, the consignee, when receiving the notification, can be sure to find his goods in the station, ready for off-loading. He can claim compensation should he have endeavoured to collect goods advised but not ready for off-loading. The *Reichsbahn* and *Czechoslovak State* alone deal with this question in detail; according to the *Reichsbahn* the expense the consignee was put to should be refunded should the consignment not be ready for off-loading within one hour at the most after the arrival of the consignee.

V. — Acceleration of the turn-round of empty stock.

The railways attach great importance, for financial reasons amongst others, to the wagons being off-loaded quickly and reloaded again without delay. The requirements for empty wagons and the number of available empties only balance approximately on small sections of the railway. Special arrangements have therefore to be made to work the empty stock to the point where it is required. The method of doing this is more or less the same on all the railways.

1. On railways with moderate traffic, without districts in which the demand for empty stock is specially heavy, wagons are dealt with according to the numbers available and the daily demands. The empty wagons are taken away and supplied by means of the ordinary goods train.

2. The large railway systems have collector stations to which the empty wagons are worked without special orders in each case, so that working them forward to the consuming centres is easier and faster. Empty wagons are attached as far as possible to through goods trains (i.e. which do not stop frequently).

3. In the case of large numbers of empty wagons for regular consuming centres, permanent or temporary instructions are in force for regularly working all the empty wagons or certain classes of empty wagons to these districts. It is definitely laid down on certain railways that the empty stock must not be operated in the direction opposite to the general direction, and the observance of this rule is closely checked, especially during periods when heavy demands are being made.

4. Empty stock trains are run under the conditions mentioned under 3; railways on which empty stock has to be run long distances work such trains regularly, or according to need, in services in which the turn-round is not constantly uniform, so as to avoid unnecessary standing, which involve shunting and loss of time. The speed of the empty rolling stock trains is the same as that of the goods trains, and their standing times are reduced; their overall speed is higher than that of the goods trains.

5. The *Reichsbahn, Austrian Federal, Finnish State, Hungarian State* and *Czechoslovak State Rys.*, as well as some

Swedish Private Rys., thus stress the importance of getting a quick turn-round of the empty stock; other railways besides the *Hungarian State* and *Czechoslovak State* and *Swedish Private Rys...*, already mentioned, the *Danish State, Swedish State* and *Jugoslav State Rys.*, give empty stock priority over loaded wagons, subject to certain restrictions relating to perishable goods.

6. To the steps taken to speed up the removal of empty wagons, must be added the measures the aim of which is to put the wagons in position as quickly as possible. All railways report that the rule is to serve the station loading sidings and private sidings several times a day.

7. It is not the regular practice to advice consignors that the wagons are at their disposal except in *Denmark, Poland, Sweden* and *Czechoslovakia*; in *Jugoslavia* this is only done when requested — i.e. frequently — and by telephone as a rule. In *Austria* when the application is received, the probable time taken to supply the wagons is given. The *Rumanian State Rys.* put up notices in the yards day by day giving the names of those who have asked for empty wagons and the wagons allocated to them; no other information is supplied except on payment, when it is sent by telephone or express letter.

8. When the wagons asked for are not available, nearly all the railways advise those concerned by telephone or express letter.

9. None of the railways consulted require the consignees of loaded wagons to state the time they will be off-loaded. On some railways the consignee advises the station personally or by telephone that the wagons have been cleared.

10. The *Reichsbahn* takes special steps to improve the turn-round of the rolling stock when the requirements for wagons are heaviest, usually in the autumn. The turn-round of the empty stock can be speeded up by the following measures :

(*a*) Removing the empty wagons (and also loaded wagons) by more frequent trains the load of which can be reduced to 30 wagons and even less, when this can be done without exacting excessive work from the yards.

(*b*) Serving the loading points and private sidings more frequently, whatever the number of wagons, so as to prevent the wagons standing idle, and to gain time for loading.

(*c*) Running additonnal goods trains on Sundays.

(*d*) Putting wagons, which arrived during the night, at the disposal of the custumers early in the morning.

All these measures improve the turn-round of both the empty and loaded wagons. Certain economic principles which are justified in normal times are waved in favour of a generally punctual and satisfactory working.

VI. — Use of containers and « rail-road » wagons.

None of the railways consulted own any road-rail wagons such as that used for the first time in 1931 on the *London Midland & Scottish Ry.* On the other hand, the *Reichsbahn* has introduced road vehicles which can carry 40-ton 4-wheeled railway wagons, and others up to 80 tons; a description of these vehicles was given in the February 1934 *Bulletin* of the Railway Congress and since that time they have given satisfaction; at the present time 37 vehicles of 40-ton capacity and 2 of 80-ton capacity are in service.

As far as the countries covered by this report are concerned, containers are only used to a small extent. The information supplied on this subject is as follows :

Railway.	Type of container.	How and where supplied.	Rail transport.	How carried between the consignor's premises and station.	Re-utilisation of empty containers.	Control of turn-round of containers.
Reichsbahn.	Large containers of 3 m³ (105 cu. ft.) capacity.	The consignor applies for them at the station; no charge is made. Special transport rate.	On flat wagons.	By the consignor.	Empty containers carried free; they are used by the first station requiring them.	...
	Small containers of 1.2 m³ (42.4 cu. ft.) capacity.	The consignor applies for them at the station.	In covered wagons, especially for parcels.			
Austrian Federal.	Considering the use of 1 to 2 m³ (35 to 70 cu. ft.) containers.	The consignor applies for them at the station and carts them himself.	(No information supplied.)	By the consignor who may use the railway cartage services.	Can be used by consignee with the agreement of the railway.	...
Rumanian State.	0.25 m³ (9 cu. ft.) containers for fresh fish.	Only at the Galatz maritime station.	In luggage vans.	The business of the consignor.	Containers cleaned after use by consignee and sent back to Galatz.	Galatz station keeps a record for each container.

The *Hungarian* and *Jugoslaw State Rys.* are still in the experimental stage with their containers; the latter reports the use of large containers used to group together consignments from a number of consignors, and small containers for parcels. The *Swedish State Rys.* report the use of small containers to a limited extent for parcels on secondary lines.

The opinions expressed as regards the use of containers are that the loading of consignments not packed separately is simplified; that savings are effected in this way and that the consignments are protected against damage, as for example parcels conveyed in small containers.

* * *

Summary.

I. *Organisation of the work in shunting yards.*

1. Care is taken as a rule that the splitting up and marshalling of the trains is so organised as to meet the traffic requirements; on the railways consulted there is already great uniformity in the principles on which the work is organised, and the sequence of the different operations is based.

2. The economic working of shunting yards depends chiefly on the rational arrangement of the timetables, the object of which should be to reduce to a minimum the time spent by wagons in the marshalling yards; when the wagons stand little, they are better used and the number required is lower. When the sequence of the trains is properly adapted to the capacity of the shunting yard, the shunting staff and locomotives are better occupied.

3. It is useful, by means of a shunting plan, to get as accurate an idea as possible of the movements to be effected in the shunting yards and of the methods

Reichsbahn Division X

Shunting plan

in force from *1st July 1936.*

Station *Astadt*

Drawn up at : *Astadt*, on *15th June* 1936

Operating Office *Astadt*

Explanation of signs :

In the harmonogram.	In the track occupation plan.	In the locomotive working plan.	In the working plan of the shunting gang.
	Track occupation due to shunting operations, waiting for the operations to be performed, or train to be dealt with being in shunting sidings.	Working time. Regular operations. Additional operations. Normal shunting time of locomotive.	Shunting work: regular, irregular trains and services). Other work
	Gl. 1 Gl. 2 — In case a track is occupied by two trains, the indications relating to the second are to be entered on the outside edge of the track band.	Other operations. Work interruptions for operating reasons (passage of trains, etc.). For lack of operations, to be performed.	Interruptions for operating reasons (passage of trains, etc.). For lack of operations, to be performed.

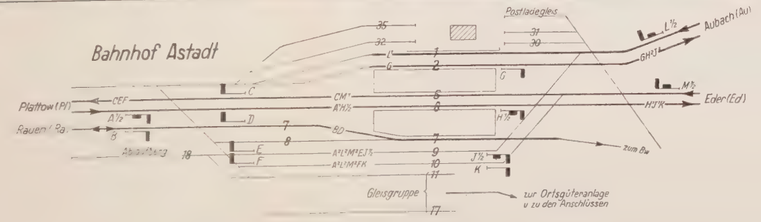
All graphical indications for passenger trains: ■ for goods trains: ▨ for serving auxiliary installations: ▩

Nos.	Stations	Nos.	Stations
1	Astadt	25	Rauen.
2	Schmieden.	26	
3	Mittelberg.	27	
14	Hammerbrücke.	28	
15	Bautenkranz.	29	
16	Eberbach.	30	
17	Wellgrün.	31	
18	Blauental.	32	
19	Forkau.	33	
24	Plattow (Pl).	34	

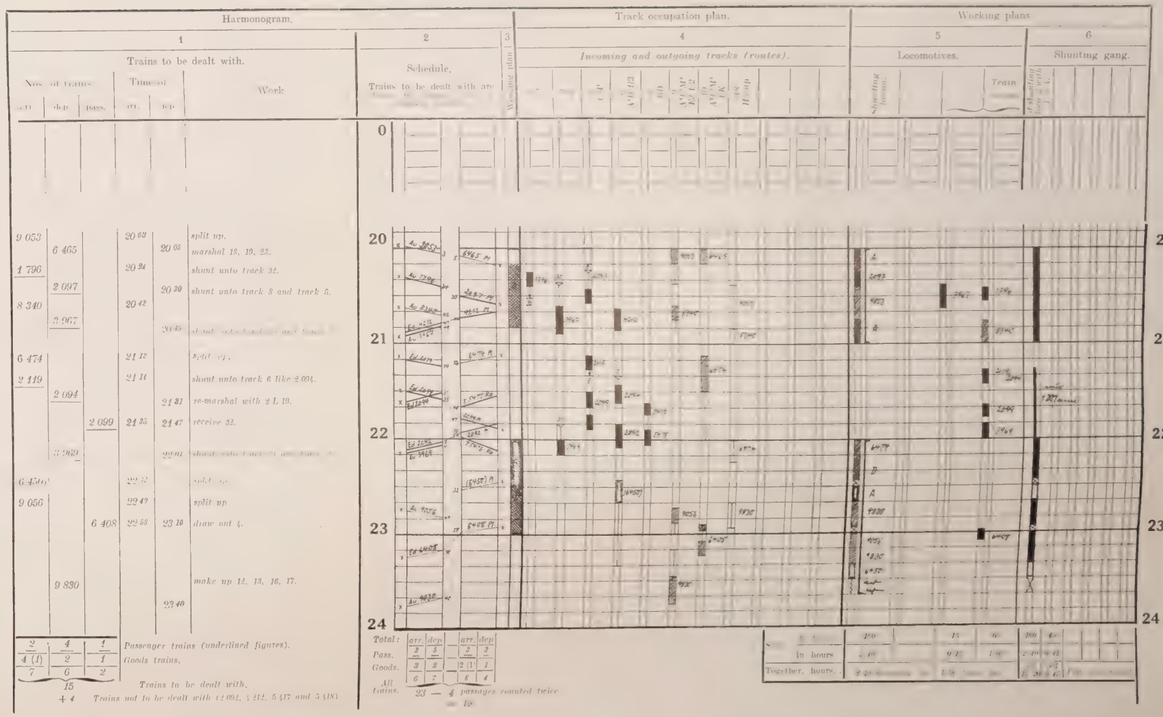
Work carried out.	Pass. trains arr.	Pass. trains dep.	Pass. trains pass.	Goods trains arr.	Goods trains dep.	Goods trains pass.
To be dealt with	17	10	10	11	12	3
Not to be dealt with	4	11	7	2	4	...
Total	21	21	17	13	16	3
All trains	60			32		

Average output per engine: Remarks:

Time spent. Locom. hours	h	min	Shunter hours	h	min
Train loco.	3	00	Foreman shunter	24	...
Shunting loco.	24	...	Shunter	24	...
Tractors	...	...	Other men	110	...
Total	27	00	Total	158	...



Explanation of German terms:
Ablaufberg = hump. — Gleisgruppe = fan of sidings. — Zur Ortsgüteranlage... = to slow goods installations and to private sidings. — Postladegleis = mail loading track. — Zum Bw. = to permanent-way shops.



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INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

13th SESSION (PARIS, 1937).

QUESTION X.

Effects of the world crisis and road competition on the railway position. Corresponding changes in railway commercial policy.

REPORT

(All Secondary Railways),

by Messrs. LA VALLE,

Inspecteur supérieur de vigilance, Inspectorat général des Chemins de fer, tramways et automobiles (Italy).

and MELLINI,

Inspecteur en chef de vigilance, Inspectorat général des Chemins de fer, tramways et automobiles (Italy).

The present report, which we have the honour of submitting for discussion at the Paris (1937) Session, forms a supplement to two papers on « The World-Crisis and Railways », published in the April and July 1935 issues of the *Bulletin of the Railway Congress*. In the conclusions of the former of those papers we expressed the hope that the agenda of the forthcoming Paris Session would again include this problem, primordial to the vitality of an important branch of railway traffic, and we wish to thank the Permanent Commission for having agreed to our request and to have once again entrusted us with drawing up the report as far as Secondary Railways are concerned.

* * *

The situation as regards operation of railways in general, and secondary railways in particular, is still unfavourable in most countries and in the majority of cases, either as a result of the world crisis or owing to the tendency of most States to render importation of goods from other countries more and more difficult, but above all, owing to the tremendous expansion of competition by road motor vehicles, which will be followed in the near future, although to a more modest extent, by aerial transportation.

If we may expect, or at least hope that present difficulties of a political and commercial nature will be overcome, it would nevertheless be extremely dangerous to cherish any illusion as to an artificial stifling of road motor competition; and that is why it appears neither possible nor advisable for industry and commerce of the various countries to adopt this unilateral solution of the transport problem, a solution which even the railways could not ask for without entirely

ignoring present traffic requirements in general and progress of the transport technique.

It is better to strive towards a rational and economic co-ordination of the various means of land transport (and eventually aerial also), and in order to achieve this aim it appears to be of the greatest importance that research undertaken by Governments and by technicians and economists should admit as the basis the fact that *Railways must be recognised as remaining the backbone of land transport.*

But the practical solution of the problem consisting in co-ordination, by rational provisions, of rail and road traffic, is a most difficult and complex matter, and it must be admitted that the dispositions adopted or now being tried out in various countries cannot have much chance of succeeding unless, when planning them, account is taken of the special situation of each individual country.

It must also be admitted that it is much easier to admit the necessity for such collaboration than to carry it into effect. One may say that among the very varying arrangements adopted or tried out in many countries most of them have only given slightly satisfactory results, or insufficient results.

In any case, the special position of each country calls for more or less different solutions.

We have, for instance in Italy, legislation that has favoured the development of public road motor vehicles for passengers, whilst only exceptionally allowing the creation of regular public goods transport by road. In France, all road motor transport has up till recent times enjoyed the greatest liberty. In Switzerland the most recently proposed Act of Parliament — not yet in force — only allowed short runs for lorries. These examples prove how much the situation varies from one country to another. In addition, for its land transport policy each country must take account of its industrial and commercial requirements, of its geographical configuration, of the extent of its railway network, of the possibility of extending the latter to mountainous regions or poor districts, and finally of the development of motor vehicles and road transport, and the chief public and commercial interests which may be concerned by such development.

At an international (almost world-wide) Railway Congress, it is therefore neither easy nor useful to discuss in detail the requisite means for a better protection of the position of railways against road motor competition; and it appears more advisable to adhere to general lines, leaving to each country the task of taking the requisite supplementary measures dictated by the special circumstances of its land transport and the particular requirements of its traffic, both general and local.

* * *

The wording of the detailed questionnaire concerning the problem which we are discussing was the same for the three reporters. As far as concerns European Secondary Railways, the questionnaire was sent out by the Association to 78 Administrations who are members of the Congress.

We have only received 12 replies of which 5 are completely negative, i.e. they just state that the Company concerned has no information of interest to communicate or else that, having regard to the very particular nature of the social situation, it is not able to reply to the questionnaire.

The seven other replies emanate from the *Régie Départementale des Tramways de l'Ain* (France) and from a group of six Swedish Railways who have added to their report very detailed and interesting facts supplied by the *Union of Swedish Private Railways.* We wish to express our particular thanks to this Union and its Director.

As to the following Companies :

(1) Piedmontese Tramways — Saluzzo,

(2) Chemins de fer de l'Indochine et du Yunnan,

(3) Chemins de fer économiques — Paris,

(4) Nord-Milano Railway — Milan,

(5) Rhætian Railway — Chur,

(6) Voies ferrées d'intérêt local — Paris,

(7) Portuguese National Railways Co. — Lisbon,

(8) Piræus-Athens-Pelopponesus Ry. — Athens,

they have added nothing further to the information they supplied for our previous reports on « The World Crisis and Railways » (*Bulletin of the Railway Congress,* April and July 1935), from which we conclude that their situation has scarcely changed, at any rate not to any appreciable extent.

* * *

The present situation of the *Swedish Private Railways,* taken as a whole and as set forth by the aforementioned Union, can be summarised as follows (the latest data applies to the year 1935).

The Private System works 9 115 km. (5 664 miles) of lines. It is composed of 87 operating concerns, of which several only work short lines. These private railways have for a long while past been affiliated to a joint organisation, the *Union of Swedish Private Railways,* whose mission it is to safeguard the interests of its members, carry out research work, conclude conventions, etc.

Thus, the *Union* organised general joint traffic and a sort of general management of rolling stock between the various Companies, as well as with the State Railways and other lines. As regards goods traffic, it was agreed to charge through transport-rates, so that railway users may consider the whole of the private railways as one single System.

The Union also handles common questions concerning the purchase of plant, changes in rates, rail-road competition, the construction of railcars, etc.

The general and detailed facts supplied by the Union lead us to consider that in Sweden the crisis period has passed; this is confirmed by the improvements ascertained in the Private Railways' traffic during the year 1934, and still more so in 1935. As regards the question of automobile competition, the eventual legislative measures adopted by the Government and the simplifications and alterations in operating methods to which the Companies have had recourse in order to retain or regain traffic, the *Union's* report restricts itself to very general considerations. But one should bear in mind the statement that Swedish railways have lost the bulk of the high-rated goods traffic carried over short distances, whilst they have retained bulky and long-distance goods traffic.

The end of the crisis period and the revival of business are confirmed by a quantity of data of a certain interest.

Both as regards quantity and receipts, the lowest mark for both passenger and goods traffic was recorded in 1932 and 1933. In 1934, and still more so in 1935, there was an appreciable improvement; the total receipts of the various lines, which fell from 81 million crowns in 1929 to 52.6 in 1932, rose to 64.8 millions in 1935.

The value of imports and exports, which amounted to 1 783 and 1 812 million crowns in 1929, fell to 1 155 and 947 millions in 1932; it rose, in 1935, to 1 470 and 1 079 millions respectively.

Industrial production, for which the index was 110 in 1929 and dropped to 87 in 1932, reached 121 in 1935.

Agricultural production has also increased during the last few years owing to protectionist measures, especially as regards cereals and sugar.

The *Union's* report states that there are

no general transport statistics for all the Swedish private railways, subdivided into categories of goods, and declares that it cannot, consequently, give a detailed reply concerning the influence of the crisis on the composition of traffic.

The economic position of the private railways is summarised as follows :

Years.	1929	1930	1931	1932	1933	1934	1935
Net profit (+) or deficit (—) in millions of crowns	+ 6.9	+ 1.9	— 5.2	— 8.2	— 3	+ 7.1	+ 6.9

These results are given in a more detailed form in the table hereafter :

Year.	Number of Companies having a		Net profit, millions of crowns.	Deficit, in millions of crowns.
	net profit.	deficit.		
1929	49	62	10.3	3.4
1930	44	66	6.4	4.5
1931	27	76	2.7	7.9
1932	23	79	1.6	9.8
1933	33	65	3.3	6.3
1934	40	55	9.7	2.6
1935	41	51	9.3	2.4

Thus the profits and deficits actually kept pace with the fluctuations of the economic situation, but once the crisis was overcome, it was automobile competition which constantly prevented a decisive improvement of the operating results of the various lines. The financial situation is therefore considered as unfavourable for the private systems, and the evolution of traffic, in the case of several of these railways, still does not show any definite signs of improvement in the future.

As regards steps taken to meet road competition, the *Union*'s report refers to the detailed data supplied by the Companies who have replied to the questionnaire.

The report itself only mentions that in several instances, with a view to reducing overhead expenses, railways have arranged with one another to adopt a joint management and that several amalgamations as to ownership were effected during the crisis, although there is no plan for an all-round amalgation.

As regards legislative measures concerning the use of lorries, the *Union*'s report states that their maximum width is 210 cm. (6′ 10 3/4″), whilst there is no restriction as to length and that the maximum weight allowed on each wheel (load included) is 2 tons.

The tax on motor vehicles is calculated according to the weight (including the driver, spare tyres, petrol, water and tools but not including the load). On the said weight, less 600 kgr. (1 320 lb.), the tax is 14 crowns per 100 kgr. (220 lb.) with a minimum of 60 crowns. For trailers the tax is calculated according to the loading capacity and varies from 30 to 100 crowns. Producer-gas driven lorries pay half the tax.

The tax on petrol is 0.10 crown per litre and on other fuel oils 0.07 : the tax on tyres is 3.50 crowns per kgr.

The granting of transport licences for road traffic is obligatory and is the task of the Prefects, who also decide as to the maximum weight and passenger-capacity. Control and inspection is by the police.

The national legislation contains no prescriptions as to wages, working hours and service conditions of drivers, except that a professional driver must not work more than 12 hours per period of 24 hours.

Finally, as regards the national legislation concerning railways, the *Union*'s report gives the following particulars :

(*a*) the Government grants neither subsidies nor guarantees and gives no financial aid to railways for helping them to meet road motor competition;

(*b*) transport for the Post Office is effected by the railways against payment;

(*c*) no reduced rates are obligatory for workmen's morning trains;

(*d*) the maximum rates (both for passengers and goods) are decreed by the Government;

(*e*) the eight-hour working day is enforced.

* * *

As regards the commercial policy followed by the various Railways the replies supplied by six Administrations are as follows :

(a) **Göteborg-Dalarne-Gävle Railways** (including the Bergslagen, Gävle-Dala and Södra-Dalarne Railways) :

During the crisis recourse was had to a certain extent to the more restricted working of the higher classes of passenger coaches in favour of 3rd class, as well as to other economic measures, viz.: unstaffed stations, trains having no guard, shunting locomotives replaced by locomotors, etc.

Road motor competition has been severe, but the railways still retain heavy and bulk traffic.

The rationalisation of transport has brought about innovations in the commercial department. A certain number of officials act as traffic canvassers. They are selected from among the officials and employees of the companies. A special instructional course is organised for such officials. They make personal visits to persuade manufacturers and traders to use the railways for their transport requirements; these canvassers do not receive any commission, but they receive an increased salary. The company has not yet drawn up any scheme for the radical alteration of the commercial department and restricts itself to a constantly increasing publicity, carried out in its name within the country and jointly with carriers in other countries. Advertising has been specially intensified to get goods traffic and, taken all in all, the outlay for same amounts to 2 $^{0}/_{00}$ of the receipts. As a rule it consists mainly of advertisements in daily newspapers and periodicals. For the passenger traffic and tourism, recourse is had to guide-books, pamphlets, films, educative trips for journalists and travel agencies; subsidies are granted for touristic publicity abroad.

As regards the commercial policy — passenger and goods — the Company has supplied the following information :

Passenger traffic. — The greatest comfort has been provided in sleeping-cars, restaurant-cars and the ordinary coaches on long-distance trains, as well as in 3rd-class carriages on suburban services.

The restriction to a single class (3rd-class), to which recourse was had for particular reasons, has been abandoned. In order to meet road competition, it was recognised that it was of the utmost importance to increase the number of ordinary trains and in the second

place to adopt higher speeds. Local trains are destined to make the greatest possible number of stops and consequently it was possible to reduce the number of stops on long-distance runs, with a resultant shorter running time. No additional charge was made for these trains. The company is considering the discontinuation of a few trains and their replacement by omnibus services run and managed by the railway itself. In order to increase rail services, light trains have been introduced, hauled by small economical locomotives, the driver of which also sells and checks tickets. In other instances, railcars have been put into service, staffed by only one man who carries out all the duties. Small ticket printing machines as well as money exchanging machines are used.

Large railcars are being tested, and their development is being followed with interest. On these railcars and for all local trains one single class (3rd) has been adopted.

On another hand, this Company has made certain concessions as regards rates and travelling facilities.

« Bathing tickets » are issued at special prices and are available every Sunday in summer; there are also « market tickets » at half price, available on certain trains every weekday; combined circular rail-road and rail-boat tickets; week-end tickets including meals; tourist tickets for the spring and autumn seasons, including complete board.

All these improvements to the technical and commercial branch of operating and the travelling facilities and simplifications have succeeded in restricting the consequences of road competition (due principally to public vehicles) and regaining part of the lost traffic. The company finally reports that rates for public passenger-transport by motor vehicles have not been increased much in recent times and that for such transport luxury vehicles have not been ordered so far.

Goods traffic. — As regards goods traffic, the company has made considerable improvements to its service.

The acceptance of goods at all hours is authorised, provided there is a staff on duty. Transport is carried out more rapidly than formerly. Goods trains also travel at night; transhipment has been suppressed by loading into through wagons. The speed of goods trains has also been increased.

A door-to-door service has been organised by making arrangements with private cartage undertakings. For certain goods services, the Company has already used containers.

Particular care has been taken over the new types of very modern wagons : high capacity and large floor space, refrigerated and heated wagons.

The Company is tending towards the lowering of goods rates and a modification of the classification. It has already adopted special export rates for certain categories of goods and has made agreements with industrial firms for a sort of monopoly for the carriage of their goods.

Storage of goods is possible at each station and the rates to be collected for this are lower than previously.

Regulations as to the carrying of goods have been made less rigorous. Claims are also met on a more liberal scale in case of loss or damage; the requirements as regards the packing of all sorts of consignments have also been made easier.

Consignments of an urgent nature are forwarded, on request, by passenger trains, usually without any extra charge.

The Company has set up subsidiary Companies for operating road transport, whilst in other instances, in order to meet competition, it has granted reductions on the prices of tickets and on the goods rates.

As regards road competition, the Company's report stresses the fact that, in order to lessen unemployment, the State has favoured the improvement of roads.

Owing to this, road competition has become keener, aided by the rapid progress of internal-combustion engines and the ease of finding labour. Consequently this competition is increasing to an alarming extent, aided by the organisation of goods « collecting centres » by road carriers, by the organisation of door-to-door delivery and other facilities. This competition comes from both public carriers and private vehicles; but the latter are preferably used for short distances.

* * *

The five other Swedish Private Railways who have given detailed replies to the various points in our questionnaire are the following :

(*a*) Nora-Bergslagen Railway;
(*b*) Göteborg-Boras-Alvesta Railway;
(*c*) Helsingborg-Hässleholm Railway;
(*d*) Kalmar Railway;
(*e*) Halmstad-Nässjö Railway.

The work of unification and co-ordination accomplished by the Union of Swedish Private Railways and the research to which the Union submits all general questions concerning innovations and changes to be made in the operation, rolling stock, etc., show that the detailed replies handed in by these five companies do not differ much from the reply given by the *Göteborg-Dalarne-Gävle Railway* and reproduced almost in-extenso above

We think it therefore more advisable to restrict ourselves, as regards the other Swedish Companies, to facts of some importance which show appreriable differences.

(a) Nora-Bergslagen Railway.

During the year 1935 an increase in bulk goods traffic was observed, this being the consequence of greater industrial activity. The Company has consequently increased its rolling stock; but at the same time, road carriers increased their competition. However, the motor coach and motorbus lines are under the control of the railway, which has organised throughout the whole region public transport services run directly under its management, and has already replaced certain passenger trains by road vehicles. The receipts from these road-operated services amount at present to 35 % of the receipts from rail-borne traffic.

Nevertheless outside automobile competition exists, and has a tendency to increase, even as regards heavy transportation.

(b) Göteborg-Borås-Alvesta Railway.

During the year 1935 an increase in passenger traffic was noticed, whereas goods traffic declined, in particular timber exports and coal imports.

On the contrary, road traffic increased, owing to part of the rail traffic having gone to the road. Competition is growing principally, both for passengers and goods, from public motor services.

As regards simplifications and improvements made in the goods service, the Company has introduced guaranteed services (e.g. for the transport of bananas), whilst a lowering of the rates and lessening the number of classes are being considered.

(c) The Helsingborg-Hässleholm Railway.

The year 1935 showed a general increase in traffic as compared with 1934. It can be estimated at about 2.3 % for passengers and 3.6 % for goods. On the other hand, automobile competition increased up to the end of 1935, in spite of the railway having considerably reduced its rates. In several instances it was not possible to retain rail-traffic, especially as regards agricultural products.

The Company bought up motor bus services which competed with it; they are now worked by the railway.

As regards goods traffic, the Company resorted to advertising by means of hand-

bills showing the times taken for transport, and to regular visits of officials to traders and other rail users. Stations and employees inform headquarters of the possibilities and conditions under which traffic can be acquired.

In many cases the company has replaced heavy trains by light trains (railcars) and has intensified its services by other light trains (railcars) running in between fast through trains. As regards goods traffic, the tendency is towards a general rates reduction and special agreements with big firms, based upon a minimum tonnage and the handing of all their transport to the railway.

The Company allows consignors to leave their goods in the wagons at ports, whilst awaiting the arrival of steamers.

The sharpest competition is from private vehicles on short runs, and public vehicles over long distances, and there is a tendency to increase up to 5 tons the capacity of motor lorries.

According to the opinion of this Company, there are already in Sweden too many lorries for normal requirements.

(d) **Kalmar Railway.**

During the year 1935, an increase in passenger and goods traffic was noticed, and this in spite of reduced timber exports. Motor competition, which was already serious, has increased considerably.

The Company inclines towards a goods rates reduction and special arrangements with the biggest firms, including lower carriage charges.

It is considering the necessity of buying up public road services already in existence and which compete with it.

Traffic is still going over to the road, although there is a tendency for matters to become stabilised. Only in certain special cases has traffic been recovered by the railway.

It has also been noticed that competition is becoming more serious over long distances.

(e) **Halmstad-Nässjö Railway.**

During the year 1935 an increase in passenger traffic was recorded; goods traffic also increased, in spite of reduced exports of timber, chemical fertilizers and paper.

Motor competition is still increasing over distances up to 100 and 150 km.

The Company is trying to keep its goods traffic thanks to the efforts of traffic agents, and considers that it is advisable to reduce rates, combined with special export rates and transport agreements.

As regards passenger traffic, the Company has already replaced certain trains on its secondary lines by motorbuses worked by itself, and is tending towards more frequent communications by putting railcars and motorbuses into service. It is seeking to buy up competitive road transport undertakings.

* * *

The *Régie Départementale des Tramways de l'Ain* (France) has also replied to the questionnaire by giving detailed information of the greatest interest. It is here a question of a system of secondary lines which, in the past, covered over 400 km. (250 miles); this system is at the present day reduced to 242 km. (150 miles) [plus 30 km. (18.6 miles) of new lines], 179 km. (111 miles) of railway lines having been abandoned and replaced by road services.

During the year 1935, receipts from passenger and parcels traffic were up to the 1934 level, whereas goods receipts declined 25 % owing to the total lack of export-traffic, reduction of inland transport and lower rates made necessary by road competition; road carriers themselves are suffering from this competition and are booking loads at any price.

The year 1935 was characterised by the hopes engendered by co-ordination among road carriers, and the latter en-

deavoured to keep their vehicles running, in order to put this fact forward when traffic will be eventually apportioned.

As regards commercial organisation, the Company allows quarterly premiums to operating-controllers, in proportion to any new traffic brought to the railway.

Publicity is intensified by means of posters and handbills, drawn up by the railway offices, and which also show, where it is considered advisable, the rates and timetables of neighbouring systems. Publicity expenses may be estimated at 2 $^{0}/_{00}$.

As regards legislative steps towards rail and road co-ordination, this Company informs us that co-ordination is only contemplated, and that decrees in force are being less and less observed.

On passenger services, the system of one single class has been adopted as a rule; the same applies to motor vehicles.

Operation has been modernised in the sense of an all round acceleration of ordinary services and more frequent communications. However, passengers only return to the railway when the latter offers more favourable conditions (fares and comfort).

The most harmful competition, in particular in small localities, comes from private cars; it cannot be estimated.

As regards goods traffic, the Company has simplified its tariffs; but motor lorry services are constantly increasing, especially within a radius of up to 25 km. (15 miles) which distance shows a tendency to increase. Competition is increasing above all in the case of complete lorry loads over any distance.

The Company has set up lorry services as feeders and for the purpose of tapping large centres whose traffic evaded the railway; further rail services are being replaced by road services as opportunities arise.

In goods traffic, the increase in road competition is due to the public carriers, whereas in practice private parties only carry out their own transport within a radius of 20 km. (12.4 miles) on the average, only possessing as a rule vehicles that can carry small loads.

Lorry loads tend to increase; on principle, however, these loads are restricted by a decree forbidding the introduction of vehicles of over 18 tons when loaded.

French legislation provides, in addition, that the maximum length of lorries must not exceed 10 m. (32′ 10″), nor their width 2.35 m. (7′ 9″).

As regards the situation in Italy, we are able to supply some information concerning the largest system operated by a private company. viz. the *Nord Milano Railway.*

In order to meet competition from lorries, which had reached considerable proportions, and had extended to almost all the localities in the rich Lombardy lake district served by its lines, this Company took advantage of ministerial decrees authorising temporary rate reductions and alleviations of transport conditions, with a view to retaining, developing or recovering goods traffic.

With the aid of these provisions, the Company concluded agreements granting lower rates to the principal firms in the district, including the organisation at its own cost of door-to-door transport in order to be on the same footing as competing road carriers, by avoiding transhipment, the risks of same, etc.

At the same time, the Company took steps to make goods traffic on its system more flexible and up-to-date.

In particular, it sought :

(*a*) to accelerate transport and delivery;

(*b*) to constantly develop grouping of goods by means of collector wagons ;

(*c*) to eliminate stops at main stations by introducing through runs, new modern platform installations for loading, unloading and warehousing goods;

(*d*) to reduce, above all, rates for accessory services performed by the rail-

way or its contractors, for using sidings, cranes, for weighing, transhipment and cartage.

All these facilities and improvements have recently succeeded in sufficiently checking road competition.

In 1934 the agreements made with firms amounted to about a hundred, covering a total quantity of nearly 150 000 tons of goods; in 1935 it concluded 140 agreements covering 250 000 tons in all.

In 1936, when a Ministerial decree came into force concerning the application of a tax of 12 centesimi per tonne-kilometre on goods transport by lorry and a super-tax of 10 % and 15 % on grouped transport and complete wagon loads, the concessions were restricted to the most important firms and contracts for a big tonnage. Nevertheless, in 1936 the agreements amounted to 120, covering at least 350 000 tons, and this quantity was considerably exceeded in actual fact.

As regards passenger traffic, the Company, in pursuance of the Ministerial decree allowing temporary concessions for this traffic also, either for meeting automobile competition or for taking account of requirements for parties, tourist traffic, etc., introduced tickets for popular trains, week-ends, trips to the large towns and so forth, in conjunction with other railways and the services of lake steamers, road services, funicular railways, etc.

In addition, the Company issued very cheap tickets to traders for travelling to markets, fairs, etc., and to encourage family groups to travel by train.

For public holidays, special return tickets at very cheap rates were issued, in order that the public might get to know the artistic, touristic and historical beauties of the region; the results were very satisfactory.

For carrying large numbers of passengers on the occasion of mass manifestations, recognised public meetings, etc., the reductions sometimes amount to even 80 %.

* * *

The *Société des Chemins de fer de la Méditerranée,* who operate for the « Centrale Umbra » and « Apennino Centrale » (Perugia) railways, also informs us as to technical and commercial improvements of great interest.

The single-phase electric standard-gauge Terni - Perugia - Umbertide line, 114 km. (71 miles) in length (Centrale Umbra) has in the last few years replaced almost all its heavy trains by light trains hauled by electric motor coaches built in its workshops, making use of existing motive power and rolling stock. The Management is at present considering the construction of light electric or diesel railcars in order to intensify the service by means of through trains, by prolonging trains from the State Railways on neighbouring lines which are operated by steam or D.C. electric traction.

The Arezzo-Fossato narrow-gauge line, which has a length of 134 km. (83 miles) (Central Apennine), was operated by steam and with old rolling stock which no longer met modern requirements. In order to meet all kinds of competition and to regain the greater part of the traffic it had already lost, the Company has had recourse to diesel railcars in order to improve and intensify its services.

The transformation is still going on, but already the former three daily passenger trains in each direction have been increased to seven, the operating expenses being only very slightly above those for steam traction, whilst receipts have risen by 50 %. The complete run of 5 h. 30 m. has been reduced to 3 h. 50 m.; the commercial speed has increased from 24 to 36 km. When the programme of transformation and motorisation of the line is complete, the new diesel bogie railcars will enable the

company to still further raise the train speed and frequency. In conjunction with these technical changes, the Company has adopted a tariff policy more favourable to the public, both as regards passenger and goods services.

Season tickets at much reduced rates have been issued in favour of workmen, students, etc. Tickets at a reduction of 50 to 70 % are issued on public holiday dates. In summer, popular trains are run at very low rates.

Thanks to these various concessions to the public, and above all to the improvement of the services, the Company has succeeded in meeting automobile competition in a very encouraging manner and in obtaining a 50 % increase in receipts.

The question of recovering goods traffic was thoroughly investigated. In order to handle practically the whole traffic of the district the Company :

(*a*) Improved tariffs and rail transport conditions;

(*b*) Itself operates road services;

(*c*) Took other special measures.

(*a*) The special concessions as regards tariffs are not general, but have been granted to each firm which guarantees a minimum quantity of traffic in accordance with the possibilities of each industrial establishment or organisation and the requirements of competition. Thanks to this procedure, which is legal, all carriers are able to open negociations with the railway before handing their traffic to road lorries.

(*b*) The Company has bought up a certain number of private road motor services, which have worked hitherto at full capacity. Transport thus effected can be classed as follows :

Transport in conjunction with the railway	40 %
Transport which would have been lost to the railway	50 %
Transport in competition with the railway	10 %

The operating results of these motor services have been very appreciable. After a short period of competition, private carriers, whose financial means were not very great, preferred to collaborate with the railway in order to retain sufficient traffic for their purposes, and the Company has handed to them an important part of the feeder traffic.

However, the most important result is that the public is starting to recognise the railway offices as the real traffic offices of the district either for rail traffic or for goods that can be carried cheaper by road; in each office the public can decide as to the advisability of selecting one or the other method of transport, collection and delivery, etc., and when it is a question of a considerable quantity of goods the public can obtain important concessions. On the other hand, this system is equally favourable to general transport economics.

(*c*) Finally, the company grants decided facilities for building sidings, warehouses and elevators on railway property; it grants very low rates for storing goods in the railway warehouses and door-to-door services have been much extended.

The economic results have confirmed the advisability of all these measures. On the Terni-Peruga-Umbertide line, the 1936 receipts exceeded the 1935 takings by 55 % and on the Arezzo-Fossato line by 73 %. In quantity the traffic was naturally still higher. It must, however, be admitted that these results are also due to the end of the crisis and to the present development of Italian traffic due to the creation of the Empire.

* * *

To sum up, the information supplied by the Companies enumerated above and by those with whom our previous reports dealt appears to confirm the fact that, as regards railway passenger traffic, the

worst stage of the crisis has now been overcome, and that by an intensification of communications, a general acceleration of ordinary services, the use of self-propelled vehicles, increased comfort and the adoption of one single low-priced class on such vehicles, it has been possible to meet road competition.

It nevertheless seems advisable that this competition be regulated by governmental enactments, taking into account the various requirements of passenger traffic in each country and the necessity of retaining for the railways, at any rate for such lines as are recognised as being of public utility, and have been transformed and modernised to better meet public requirements, sufficient traffic to enable them to subsist.

As regards goods traffic, the position appears to be a much more difficult one.

It must be admitted that even if railways still retain heavy and long-distance transport, they are in a much less favourable position than lorries for carrying valuable goods, small consignments and short-distance traffic. In spite of all their simplifications, tariff reductions, improvements of services, railways are still at a disadvantage. Lorries can improve the ratio between the useful load and their tare; in railway operation any increase in power or speed has to be paid for in the shape of an increase of the dead weight to be hauled; in the case of motor lorries technical progress has been able to continue almost in the opposite sense.

This technical advantage enables the road carrier to quote moderate rates which, in actual practice, give rise to other savings resulting from door-to-door transport, the elimination of transhipment, stops, etc. To offset these advantages, which for certain classes of goods and for certain distances are of decisive importance, the use of « containers » by railways cannot be considered in the majority of cases as sufficient, apart from restrictions to be imposed upon private carriers in the shape of taxes and restrictions concerning the staff, working hours, etc.

It is therefore to bring the requisite amount of order into the chaos of competition that requests have been made on all hands to harmonise the two methods of transport, either by means of agreements between rail and road, or by direct intervention of the public authorities.

The former solution has been adopted in several instances, but as a rule it has not succeeded, unless the railway has bought up the competitive lorry services and run them itself.

M. Dautry, one of those in favour of agreements, in France, said : « The railway companies must make with automobile carriers agreements that are sincere, equitable and advantageous for both parties. Agreements which do not fulfil these essentials will have no effect ». This is a very fair conception, but difficult to carry out, as is proved in practice.

In our opinion, the problem is of such vast importance, not only to railway companies and road transport concerns but also, and above all, to the general welfare of States, that in the end the whole problem of co-ordination of transportation by rail and road (and, if necessary, by inland waterways and aerial navigation) will have to be handled by the Public Authorities.

To the general problem of rational, economical and efficient co-ordination of rail and road transport there are, of course, related other questions and definite situations the solving of which can be entrusted to Governments or handled by the parties concerned.

We deem it useful to mention a few hereafter :

(*a*) There are railway lines whose receipts, already before the crisis and the development of road motor competition, could not cover operating expenses. A detailed survey of their pre-

sent situation may possibly reveal which of them can be kept running for rail transport.

As regards the others, it is to be hoped that Governmental intervention will facilitate their disappearance and their being replaced by regular road services, for passengers, and where necessary for goods also.

(*b*) In many cases organisation of transport by grouped consignments is very costly for secondary railways, whilst the average loading of wagons for such transport becomes insufficient.

In such instances it may be of advantage to have recourse to the circular automobile services for collection and delivery of goods within zones served by the principal stations of the railway. Such feeder services, by lorries, are capable of supplying remarkable profits to railway companies and enable them to run collector wagons between the various stations in order to facilitate and accelerate transport and the regular delivery of consignments.

(*c*) Under certain conditions of collaboration between rail and road the use of containers should be made obligatory and subject to general stipulations. The same applies to an extension of the use of tractors and special trucks for the transport of wagons by road from the arrival station to destination.

* * *

In *Italy*, in view of the exceptional and disordered development of private organisations carrying goods by road and with a view to better co-ordination of rail and road, a law was passed on the 20th June, 1935, which ordains that :

(*a*) all undertakings having as their object the transport of goods by lorries, on behalf of third parties and against payment, must have obtained a licence or authorization from the Ministry of Communications;

(*b*) transport of goods carried out by their owners with their own lorries is subject to a licence from the same Ministry.

The amounts to be paid for each licence, concession or authorization are stipulated by the laws of the 26th September 1935 and 20th November 1935. Finally, the law of the 2nd December 1935 decrees a new tax on the transport of goods by lorries.

All these regulations were adopted in the spirit of fascist discipline and paved the way for further measures, now under consideration, for the purpose of co-ordinating in the most rational and efficacious manner the various competitive means of public and private transport.

With the same end in view, the agreements made or to be entered into by the various parties will be examined and the collaboration of these parties will be very useful and will be facilitated by the corporative organisation of the State, which will prove also providential in this field.

* * *

In *Germany* the law of the 26th June 1935 (put into force on the 1st April 1936) laid down the following guiding principles regarding goods traffic :

(*a*) To transport goods on behalf of third parties beyond the boundaries of their localities and within a radius of over 50 km. (31 miles) all concerns or persons must have obtained a licence.

(*b*) All carriers thus authorised are united in a recognised public Association called « State Society for Motor Transport », which is under the direct supervision of the Ministry of Communications.

(*c*) The rates are published and drawn up by the Society in collaboration with the Railway; they must be approved by the Ministry of Communications. All departures from the said tariffs are

strictly forbidden and each consignment must be accompanied by a waybill.

(*d*) The Reichsbahn may carry out long-distance transport by means of its own lorries; but the Ministry of Communications has power to restrict them.

* * *

In *France* the position appears to be more complex, in view of the existence of a railway system of nearly 50 000 km. (31 000 miles), 1 million lorries of much varying carrying capacity and 26 000 km. (16 150 miles) of inland waterways.

A law passed in April 1934 set up within the Ministry of Public Works a Co-ordination Committee which, through the medium of departmental Committees, has to facilitate and bring about district agreements for the better organisation of passengers and goods transport by rail, road or waterway. If no agreement can be obtained the case is settled by arbitration.

* * *

The steps taken in Italy, Germany and France, and explained above, and similar measures already in force or under consideration in Switzerland and most other countries confirm the advisability (and sometimes the necessity) of having the problem of competition between rail and road examined and solved by the Public Authorities, in order to attain the most rational and general solution of a situation which, in the majority of cases, is of sufficient gravity to preoccupy the transport industry and, by its repercussions, also affects the economic position of the State. The considerations set forth in the preface of this report and which were mainly deduced from the conclusions of the two previous reports on « The world crisis and railways » appear to be once more confirmed as regards their general outlines, except the transitory question of the world crisis, the worst period of which is now past.

* * *

SUMMARY.

As the result of these remarks, statements and findings, we feel we can summarise our report as follows :

1. The worst period of the crisis may fortunately be considered as now past. Nevertheless, it is to be hoped that international trade, freed from the hindrances still prevailing, will revive to its former extent and thus bring about a rapid and permanent intensification of traffic by the various means of transport : rail, road, waterway and aerial navigation.

2 For the fundamental functions of *mass* transporters and long-distance carriers, railways must be looked upon as the backbone of all means of communication in all countries. All other kinds of transport should be expanded to most usefully meet the requirements of each country taking into account the needs of the various districts, the eventual gaps in railway systems and the aim to be achieved, viz. to render all transport the most economical, rapid and useful for the district served. When competition between rail and road becomes strong, dangerous and anti-economic, the intervention of the Public Authorities is desirable, for imposing regulations to coordinate the various means of transport.

3. In the case of secondary railways of a local character, whose operation shows a deficit of an endemic nature, it is desirable that in each State the public authorities investigate their importance and utility, having regard to the requirements of the district served. When there are well founded reasons for keeping them in operation, State intervention to assist the transformation and modernisation of such railways is highly

advisable. If the traffic requirements are not important and if modernisation of the railway entails heavy sacrifices, it is preferable to definitely abandon the line and create modern public road services.

4. When the requirements of a district demand the simultaneous presence of public transport by rail and by road, concentration of the whole traffic in the hands of a single company is advisable. In any case, certain secondary trains carrying light traffic may be advantageously replaced by road motor transport.

5. The operators of light railways should bear in mind modern requirements of passenger and goods traffic. In the case of passenger traffic, in particular, communications must be made frequent by putting into service light and fast trains providing the maximum of comfort for passengers. For fast railcar services (electric or internal-combustion engined), a single class is as a rule to be recommended. Goods rates should be made as simple as possible; hindrances of all kinds of a bureaucratic nature should be avoided; transport rates should be such as to develop commerce; transport and delivery should be as rapid as possible; the necessary connections with road transport should be provided for door-to-door collection and delivery and for creating feeders for the railway. Finally, one should try to avoid transhipment, re-forwarding from junctions and lack of connections between the various railway systems. For certain goods an increased use of containers and the transport of wagons by road to factories, etc., by means of special road vehicles, are advisable. It might also be of interest to look into the question of transporting loaded lorries, between large cities far apart, by through trains run during the night, in order to reduce the expenses and increase the rapidity of transport.

Rome, January 1937-XV.

[625. 61 (01]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

13th SESSION (PARIS, 1937).

QUESTION XII.

Co-ordination of operation as between main-line and light railways.

REPORT

(All Countries) (*),

by Messrs. BELMONTE,

Chef de service au Service Commercial, Italian Stale Railways,

and L. TOSTI,

Chef de service au Service du Personnel et des Affaires Générales, Italian State Railways.

Foreword.

This question was already discussed at the Cairo Congress (1933).

It appears to us that the particular reason for which it was again included in the agenda of the Paris Congress was inspired by the desire to make clearer a question which had been worded in perhaps too broad a sense, and consequently somewhat vaguely.

We therefore considered it necessary to circumscribe our investigations and keep strictly within the limits so traced. With this object, we made our questionnaire as detailed and precise as possible. We had however to take into account a conception which differed from our own to some extent, and tended not to limit the meaning of the phrase « co-ordination in operation ». Consequently, we followed up our questionnaire by a recapitulative enquiry in which we asked our colleagues whether they thought it possible to give the phrase « co-ordination of operation » a wider meaning than that given it in the questionnaire.

The replies received nearly all coincided with our own point of view.

We will therefore consider co-ordination of operation between main-line and light railways (1) as we have defined them from a double point of view :

(a) *as regards the user* — as putting into operation a single public service

(*) Report drawn up in common with M. Delille, Directeur de la Société Générale des Chemins de fer économiques (France).

(1) The questionnaire was preceded by the following remark : « We understand » by « light railways » those which on account of their length, as well as their » markedly cheaper construction and operation, serve the traffic requirements of limited areas, or that of regions little developed » economically. By *light railway* we mean » therefore all secondary, local, district, Nebenbahnen, etc. railways, even when considerable distinctions are made between them » by the legislation of some countries ».

over the whole or greater part of the railway lines in a given territory, so as to eliminate the drawbacks, difficulties, additional cost, and as fas as possible the inconvenience due to passengers and goods having to pass from the lines of one railway to those of another ;

(b) *as regards the relations between carriers* — as a close collaboration, even going as far as the carrying out of operations by one railway on behalf of the other and reciprocally, in order to make more regular, more flexible, and faster the service each of the railways has to give to the public.

We consider, moreover, that the objects aimed at by the co-ordination of the different railways should be so achieved that each unit maintains its autonomy and personality, as well as the characteristics of the particular function it has to fulfil. For this reason we will not deal here with the measures taken by each main line railway, to fit in its own main line services with those over its branch lines. Nor will we consider those measures intended to reduce the cost of working a main line railway's branch lines. The mere fact that these lines are included in the main line railway system automatically ensures co-ordinated operation.

This does not mean that we think it impossible to reduce expenditure, and bring about closer contact, and more community of interests, to the profit of one or other group of railways or both, by other kinds of measures of co-ordination, sometimes limited to the working alone ; but these measures instead of co-ordinating and combining *existing relationships* to suit the end in view, would effect such radical changes in these relationships as to lie outside the limits we have set ourselves.

On the other hand we consider, and must insist upon this point even at the risk of repeating ourselves, that the co-ordination we are investigating is that which, when it fails or is insufficient or imperfect, immediately affects only exchanges of traffic between the main line railway as a whole, and one or several light railways forming autonomous and independent units. Useful advice could be given and suggestions made on co-ordination of this kind, without affecting the internal working of the railways.

Consequently this investigation is into one particular side or normal railway working. If through certain happenings (world economic crisis, serious competition from road transport) the importance of this question has increased, or rather become of greater interest to the railways, the problem forced itself from the beginning of the railways on the attention of the technicians, managers, and investigators, and sometimes even legislators agreed as to its importance and complexity, even when only considering it from the point of view of the economic and social functions the railway was, and in our opinion still is, destined to fulfil.

Obviously, the many difficult judicial, financial and technical questions co-ordination involves cannot be solved in a short time. This is the more easily understood that the most logical solutions to certain questions, and not the least important ones, immediately bring into play antagonistic interests. There is no doubt, therefore, that even to-day it is most necessary to know, study, and discuss all the solutions experience in the different countries has shown to be the best, so that the experience of each may become the experience of all.

This may explain the few answers received to the questionnaire sent to 104 Railways : only 36 answered, and 15 of these through courtesy alone. Only 21 Railways therefore collaborated with us and gave us any information about their practices and investigations.

We tender our most sincere thanks to these effective collaborators as well as to the railways who expressed opinions

or reported tendencies with which we did not always agree, though they gave us the opportunity of going into the disputed facts more thoroughly.

We have tried to discuss the arguments in question without going into details nor considering each particular case. Perhaps we have not always been very successful. The questions with which we are dealing concern the working and are in consequence always questions of detail. To have treated them in any more general way than we have done would have made our report too vague.

Before ending this short foreword, the object of which is self-evident, we must outline the way we classified the different questions.

We deal in turn with :

1. Connections and station plant as means of co-ordination ;

2. Principal operating conditions best able to further efficacious co-ordination;

3. Some accessory operating conditions.

* * *

I. — Junctions and installations.

As the main line railway was the first built, the light railway is usually connected with it by lines running into one or other of its stations, which for this reason are called junctions or connecting stations.

This practice is necessary to safeguard an incontestable prior interest from both the public and private points of view. Only exceptional local conditions, of a topographical kind in particular, can justify any derogation thereto.

The connection is made subject to an agreement freely entered into by the railways concerned, or in some countries in accordance with the law. This is a very satisfactory state of affairs, at it shows that the authorities are alive to the need for co-ordinating the activities of the different railways in the general interest and also that transport undertakings appreciate the mutual benefits of getting together and solving their common problems.

If the secondary line is standard gauge, the connection or junction station can be turned into a joint station. The centre is then served by the two railways by means of a single station, and the joint use, though it may not extend to all the station equipment, nevertheless applies to an important part of it.

The two railways although of the same gauge may, however, have separate stations in the same town. The connection then consists of a line leading from the nearest station on the secondary railway to that of the main-line railway. As in this case there is no joint use, but each railway covers its own services in its own station, the secondary railway must have at least the equipment necessary to deal in its station with traffic exchanged between the two railways, in which station, as we will explain at greater length further on, certain operations must be carried out on behalf of the other line. When this is the case, the passengers are also obliged to go a longer or shorter distance to get from one station to the other off the railway premises.

From the purely objective point of view, there is much closer co-ordination when there is a joint station, and this solution is to be preferred.

On the other hand, as cost must never be overlooked in problems of this kind, the Italian legislation would seem to be very cautious in this respect. This legislation, considering that the junction station, which belongs to the main-line railway and often serves important urban centres, can be worked in a way quite out of proportion to the financial resources of the secondary railway, stipulates that the latter may have joint use of a main-line railway station on condition that the cost of adapting the existing equipment and the expenditure involved

in joint working do not exceed respectively the capital cost and working costs of a separate station capable of meeting the requirements of the new line — and, as shown in practice — of meeting the aesthetic standards of the centre served.

Taking into account these restrictions, which in fact correspond to the general practice of providing separate stations only when the traffic exchange between the connecting railways is relatively unimportant, joint stations are always advisable for railways of the same gauge whenever the local topographical conditions lend themselves to the requirements of the light railway. In this case, the light railway should use the existing equipment of the main-line station, as far as possible so as to limit to the indispensable minimum any further equipment required either for common use or, on the contrary, for the exclusive use of the light railway. Obviously, rather than going to the other extreme, which would burden the light railway unnecessarily, the joint use should be limited to those parts of the station considered necessary and sufficient for the needs of the connecting line.

It appears that a joint junction station is not to be recommended when the gauge is different, unless it is possible to insert the narrow-gauge track between the standard gauge track on the running lines and shunting sidings, as well as on the passenger and goods service lines. These are quite exceptional cases, as such a solution would be costly owing to the size of main line stations, and to permanent-way complications ; the division of the costs would be intricate and difficult, as it would be far from easy to determine the actual use made by each railway of the equipment in question.

When railways of different gauge are connected together the joint use arrangements can vary considerably.

When, for example, the narrow-gauge lines are entirely or partly in the same zone as the standard gauge lines, each narrow-gauge line lying beside a standard-gauge line, the joint use could extend without inconvenience to the proportion of the buildings and staff employed or to be employed jointly. A similar case arises when the narrow-gauge lines are laid or grouped independently alongside the main lines within the same boundaries.

Naturally this common use only profits the light railway when it leads to a notable decrease in the operating costs, which is only possible when the narrow-gauge railway is a complex system, carrying a considerable volume of traffic requiring relatively extensive equipment.

In the case of separate narrow-gauge lines ending at a main-line railway, it would seem preferable that the two stations built separately as near each other as possible, each meeting the particular requirements of the line owning it, should be connected by rail for the passenger and goods services. If there is a considerable exchange of passengers and the cost is not excessive, the stations should also be connected by means of subways so that the passengers can get from one line to another safely.

In cases like this, for the reasons given above, the narrow-gauge line usually runs into the main line station. As regards the transfer of goods, all that is required is a few narrow-gauge lines alongside a loading platform by the side of some of the standard-gauge lines. The junction station can always use these lines to stable any goods wagons for transhipment.

With the opposite arrangement (standard-gauge line running into narrow-gauge station), it must be remembered that the light railways do not run at night as a rule, and that in any case it will not be possible to provide the power and staff required to deal with the wagons off every main-line train in the light railway station and deliver the

goods immediately. Consequently more extensive equipment would be required, as in addition to the standard-gauge transfer lines in the light railway station, other standard-gauge sidings will have to be put at the disposal of the light railway for the reception of wagons which will have to be shunted in the main-line station and then taken onto the transhipment lines in the light-railway station, and this all means additional expenses.

Particular mention must be made of narrow-gauge line junction stations over which the main-line stock is worked by means of transporter trucks, because these methods are a great improvement from every point of view, and a very efficacious means of co-ordination between lines of different gauges.

In such cases the best plan is for the standard-gauge line to run into the light-railway station, in which transfer lines will not be required, but where it is cheaper to put down lifting equipment and to do the handling, the stock being hauled by the narrow-gauge motive power.

Similarly, the installation of track with four lines of rails to serve important works or centres not far from the transhipment places, seems recommendable.

* * *

II. — Operating conditions.

Co-ordination organisations.

When considering the operating conditions which technically and in the interest of the public and of the carriers best achieve the objective aimed at by co-ordination, as we said in the foreword, a considerable number of points present themselves for attention. Owing to the contradictory nature of the data and the interests at stake, as well as the objects pursued, it seems very difficult to reach any satisfactory agreements that will achieve and maintain the cordial relations essential for useful and lasting collaboration.

This leads one naturally to wonder whether, instead of expecting co-ordination to be achieved through bargaining and argument, it would or would not be better if the agreements in connection with the co-ordination were confided in each country to the care of an independent and consequently impartial authority, which would inspire confidence and, being in full possession of the circumstances and particular situation of all concerned, could, without their assent and wish, arrive at a decision and lay down the conditions for the desired co-ordination.

Our enquiries seem to show that there are no organisations of this kind, apart from the German *Verein* which includes all the private railways and regulates all traffic questions between the main-line railway and the light railways. Elsewhere, as in Austria, the Commercial Union of Austrian Rys, in Switzerland the Commercial Conference of Swiss Transport Undertakings, and the Swiss Goods Rolling Stock Association, and in Belgium the joint Committee of representatives of the Companies, are either organisations for carrying out investigations and deal only occasionally with general questions of co-ordination, or else their task is limited to special questions, such as rates and transport conditions, exchange of rolling stock, etc.

However attractive this organisation may appear to be at first sight, and though its usefulness from certain points of view could not be overestimated, it would nonetheless be dangerous to entrust the solution of very delicate questions on which the very existence of certain undertakings may depend, to an organisation which does not share in the life of these undertakings. Such an organisation, which would have to be set up by the State, would end, even though unwittingly, by being influenced by the

most powerful interests, in particular those of the State itself, whether it operates or merely concedes the railways.

In our opinion a useful organisation in the general economic interest would be one responsible for co-ordinating all forms of public transport, i.e. by sea (coastal navigation), river, air, road or railway. To delimit the duties and field of action of each of the above methods of transport ; to co-ordinate them so that each in its own clearly prescribed sphere and all of them in the vast field of national economics would be able to exist, adapt themselves and progress ; to put an end to competition which from the national point of view upsets the rhythm of production and wastes energy and wealth ; to allow only such competition as will keep them efficient and stimulate them towards improvement and development — all these, in our opinion, would be the tasks of the higher co-ordinating authority.

But any argument, discussion, and bargaining intented to establish the agreements on which the co-ordination of the railways is based, in our opinion, as in that of many of the Railways replying to our questionnaire, should be left entirely to those concerned.

In this connection, Governments which with laudable foresight now generally require co-ordination by law, might go even further and lay down the reciprocal duties and rights of carriers, and the bases on which compensation for services rendered by one carrier to another should be calculated ; the civil and commercial responsibilities of each party in the joint working, and finally the obligation of submitting to arbitration questions which cannot be agreed spontaneously.

* * *

Joint stations.

As in the case of the use of the equipment, the operating services can be co-ordinated most easily, fully and efficiently by means of the joint stations. The operation of the main-line railway and that of the light railway can be really merged in joint stations only, at least at the main centre of common activity of the two systems. The main-line railway which must cover all the services of the terminal station of the light railway with its own equipment and staff can share a little in the intimate life of the small system and understand its resources and operating needs, and as a result suggest alterations and improvements only when the junction station is a joint one. On the other hand, the light railway can profit, at moderate cost, from the much more extensive equipment of the main-line railway.

And if, as usually happens, the locality also served by the main-line railway is the principal centre of exchange with the other places on the light railway, it is superfluous to point out the advantages the light railway obtains from making use of this equipment which would be too costly for it to get for itself. As regards exchanges between the two systems, by working the trains from both lines into a common station, the time goods stand before transhipment is reduced to a minimum, and in addition the arrangement is more convenient for the passengers who are provided with the same facilities as they get on the main-line railway.

To conclude, there is no doubt that as far as the working is concerned joint stations are to be preferred, and the services therein should not occasion any too difficult problems seeing that all the services, including those of the light railway, are worked by the main-line railway.

The only question which can lead to disagreement is the nature and division of the common expenses.

In this connection, though we do not

think it part of our task to deal with a specifically financial question like this, which was already dealt with at length at the London Congress (1925), we would like to quote the reply received from one railway. This Administration only charges the light railway the additional cost due to the connection with its own system and reduces this amount to take into account the additional traffic brought in thereby.

We will not deal at length with the question of bringing in new traffic, as in many cases this can be disputed ; without insisting on the fact that light railways are not always feeders for main-line railways, but can also compete with them, it seems to us that the best hypothesis is that the increase in traffic is mutual.

A more important criterion seems to be the « additional expense ». We cannot see very clearly how this expense is or can be estimated. For the sake of clearness, let us refer to the expenditure under the heading nearly always most in view, that on staff. A priori, the idea that the additional expense is due to special staff kept at the disposal of the light railway must be set aside as this would undoubtedly be too heavy a burden on the light railway and reduce to practically nothing any financial profit from the joint station. In most cases, however, the light railway's services are worked by the same staff as those of the main-line railway and at the same time. When this is so and the main-line railway has to increase its staff owing to the joint working, the light railway should pay for these additional men only, even though other men of the station also work for it, and not pay anything when no extra men are needed. This method, which the replies received show is in force in isolated cases, may be recommended and is perhaps suitable in special cases. It cannot be applied generally, however, for two reasons : it is not a sound principle in railway economics to require no compensation simply because the services rendered have not entailed big expenses; and secondly it is not a good administrative principle to implicitly give the light railway a right to investigate and check the administrative methods and systems of the main line railways.

* * *

Separate stations.

If at first sight the relations resulting from the connection are simpler and therefore easier to regulate when there is a separate station on the other system in the same locality, the question is more complicated on closer examination.

The replies are practically unanimous in agreeing that the work done in the common interest is limited to transferring wagons from railway to railway, i.e. to reciprocal operations which can be compensated for. First of all, in our opinion, though it is neither confirmed nor denied by our enquiries, when both railways are of the same gauge the secondary railway should work the rolling stock in both directions between the two stations. In this way, the light railway can effect a saving by making better use of its operating facilities, as it usually has more spare workings than the main-line railway ; goods and rolling stock can easily be dispatched from the connecting station without making any special demands on the main-line railway ; in every case the responsiblity for the transport is clearly delimited.

As regards other services rendered, we think that to obtain more effective coordination, the main-line railways should not ignore nor neglect the needs of the light railways in connection with the exchange traffic. Whenever it might be useful to do so, they should, in return for adequate compensation, allow all operations likely to make the service on

the light railway more regular, faster, and simpler, to be carried out in their own station.

In the case of railways of different gauges, it is obvious that the common section must be operated by the light railway. In all cases the transhipment should be done by the light railway, the main-line railway bearing the cost.

We will not deal with the case of limited exchange traffic, when the light railway is more or less in the same position as an industrial siding as regards complete wagon loads, or an ordinary railway user in the case of small consignments.

On the other hand, the relations are not so simple when the exchange traffic is important and the secondary railway is formed of an intricate system of lines carrying traffic in different directions.

As on most light railways there are no night services and wagons can pass from one railway to the other only at rare intervals during the day, the long standing time could be used, if the main-line railway agrees, for marshalling the trains, and shunting the vehicles according to destination and station order on the light railway.

The situation would be the same in the case of small consignments ; the routes should be co-ordinated according to the methods and systems known to all those who devote themselves to this part of the service.

* * *

Through services.

In general, those countries recognising the importance of co-ordination in railway working and having passed decrees requiring the different railways to enter into joint agreements, have also been led, by the logical development of this principle, to require the same railways to introduce combined or through services, so that goods can be carried under a single waybill over several railways in turn, and thereby remove the difficulty or at any rate the additional cost of transferring goods from one railway to another.

At first sight it seems surprising that though such legislation requires through services in the case of goods, nothing is prescribed in the case of passenger services. Even when, by agreements, the carriers have made good any gaps in the legislation, the through goods services are not always accompanied by through passenger services. The justification for this is the difference in the practical and legal consequences as between the two forms of transport resulting from a single contract.

The contract between the passenger and the first carrier which also binds the subsequent carriers as a result of the through service completes its co-ordinating function in the sale of the ticket by the first carrier on behalf of any others, and from the public's point of view in the convenience of being able to effect a complete journey without having to book another ticket.

In practice it is merely an agreement between the two carriers to liquidate the respective debits and credits.

As such a service plays little part in the work of co-ordination, the legislators should not be criticised for considering it unnecessary to make such through services obligatory. It is natural too that carriers operating such services by common agreement should limit them to the most used routes.

On the other hand, in the case of goods, apart from the undoubted advantage a through service gives the consignor by freeing him from the bother of arranging for the goods to be transferred to the lines of the subsequent carrier, and by enabling him to know in advance the cost for the whole route, the legal scope of the single contract as between the carriers and as regards the public is much wider and more complicated.

It may seem superfluous to deal with ideas universally recognised and definitely admitted, both as regards their application in the domestic laws of many countries and also in international agreements. The reporters, however, think they must insist so far as they think it useful, even when dealing with the co-ordination of railways in a single country, on the adoption of some of the fundamental conceptions on lines avoiding the unequal divisions resulting from the marked disproportion between the light railway and the main-line railway.

The single contract for the carriage of goods (including registered luggage) represented by a single waybill which accompanies the goods from the dispatching main-line station to the receiving light railway station or vice-versa, apart from the above mentioned advantages, may be felt by the consignor to involve so great a risk as to make him prefer to abandon the said advantages. For example in all cases of damage or delay, to make good his claim to compensation he would have to carry out enquiries, almost an impossiblity so far as he is concerned, to prove which carrier is at fault. In such cases, the user ought to have the legal right to make a claim against the carrier with whom he is in immediate contact as consignor or consignee. The carriers, therefore, must recognise their mutual responsibilities towards the public and give up any idea of proving which one is at fault and how the other can receive compensation from him. In this connection, we do not think it possible for light and main-line railways to adopt the transactional rule adopted in international services, of dividing the damage according to the amount of money received and for greater ultimate facility, according to the mileage ; obviously this method would be too costly for the main-line railway.

In addition, to make the co-ordinated working appear to the general public like a single service, which is the object of co-ordination, we think the transit times should be calculated as though it were a question of transport over a single railway, as in the interests of the carriers themselves this will lead to closer collaboration at the junctions.

Finally, in view of the end to be attained, we do not think it should be difficult for carriers of good will to make agreements for the reciprocal representation at administrative and judicial enquiries held into claims in connection with excess charges, or insufficient charges, due to mistakes or misinterpretations of the tariffs or particular regulations by the staff of one or other railway.

* * *

Connecting services.

It is not always useful or even necessary to introduce real through services by means of which the consignments can, as far as the public is concerned, be dealt with as if they were carried over a single railway. Variations in track gauges or constructional gauges on the secondary railway prevent or limit the running of the main-line stock on the light railways. The operating conditions of the connecting lines are so different that with the best will in the world it is not possible to make the workings of one railway merge imperceptibly into that of the other. In addition, some carriers are not prepared to wait for their money the relatively long time it takes to settle the accounts of the through services.

However, we think that in these cases likewise it is not necessary to give up co-ordination of operation altogether. This applies in particular to the transport of goods ; in the case of passenger services the gauge or construction of the lines does not alter the situation essentially, and if for other reasons a through service is impossible, it is not a very great

hardship to have to buy a new ticket in the exchange station.

In the case of goods, when through services are not considered profitable, to reconcile the justifiable demands of the public with the service conditions and the interests of the carriers, formulæ have been devised for forwarding the goods without the parties concerned having to take any action at the exchange stations ; these formulæ form what is known in some countries as re-dispatching, in others as re-registration, and in Italy as « correspondence services ».

When this practice is followed, the consignor gives the first carrier a single waybill according to which the carrier in question undertakes to work the consignment over his railway as far as the exchange station (destination station of the agreement concluded), and to make a new contract with the following carrier, in his own name but on behalf of the consignor, for working the consignment from the exchange station to the final destination. We have therefore a single document with a double contract, the first relating to the direct activity of the carrier, and the second giving him a mandate for the operations which the carrier undertakes to carry out on behalf of his client (consignor.). The responsibilities of the first carrier to the consignor are limited to the terms of the contract entered into and once it has been completed he has no responsibility for the transport over the lines of the next carrier. The carriers, moreover, having come to an agreement about such services, each considers the other quit of responsibility once the goods are handed over, the second pays the former the amount due for the journey over his lines, and collects it from the consignee.

In this way, apart from special cases (transport of cattle, for example) the intervention of the parties in the exchange stations is rendered unnecessary; the accounts are settled immediately between the carriers ; and as on transhipment the goods might be damaged, the responsibility of each carrier is clearly limited, even as regards delay.

A question might arise as to the competence of the carriers to accept and settle claims. In view of the different nature of the contracts made, it does not seem possible to apply the same rules as in the case of claims arising in through services. The users should be put in a position to prove their claims easily, at least in so far as the first carrier is concerned, as by a special clause in the contract he is responsible to the person making the contract. In practice the question can be solved in the following way: the user could claim against the first or the last railway : if the first carrier receives a claim which does not concern him, he advises the user how to claim on the next carrier and sends the claim on to this carrier; when on the contrary the last railway gets a claim which does not concern it, it advises the user and forwards the claim to the other railway.

* * *

Transport rates.

Our enquiries show that the light railways generally adopt the rates in force on the main line railway, but not the special, local or exceptional rates. This is less general in the case of passenger rates, and in many cases each railway has its own rates for both kinds of transport.

This method which definitely corresponds to the sound idea of the autonomous existence of independent units according to which only such alterations and precautions as will maintain and develop each railway can be effective, seems to be a just one, and not in contradiction to any extent with the objects of co-ordinated operation. The ideal, of course, would be to make agreements by

which any facility granted by a railway would apply throughout the transport. Obviously, the differences in organisation are against this solution, and if it is contrary to the general interest to oppose the granting of special concessions by main-line railways on account of the compensation they get by the transport of large masses over long distances, it would not be just to pretend that the small railways are in the same position to obtain such compensation. At the present time, when the secondary railways, even more than the main-line railways, are feeling the harmful effects of road motor competition, the contrary can be the case. In fact, unless the fear of losing the traffic justifies it, the main-line railways cannot complain; nor should the light railways expect the main-line railways to give up the advantages they are not likely to lose. Any attempts in this direction, we think, are sure to fail, and would only cause resentment and opposition which would be prejudicial to co-ordination in many ways.

We do not mean thereby that each railway should content itself with merely seeking its own interests without taking into account the legitimate interests of its neighbour and collaborator, especially when these do not interfere with the national interests. The interests of all the parties concerned can only converge if each has the general economic position of the country at heart together with the safeguard of the proper minimum of private interests. This safeguard is essential, and consequently each railway should remain the master of its own rates so long as the rights of others and the general interest are respected.

Seeing that a properly co-ordinated working does not necessarily mean absolute equality of rates on all the connected systems, the question of calculating the total cost, i.e. the question of knowing if this should be based on the total distance or on the distances worked over each system, loses its importance.

The first method of calculation can only be used, in fact only is used, when the basic tariffs are identical. It appears to be the simplest and most attractive method in itself because it automatically eliminates many of the difficult problems which, as we shall see, arise in connection with the routing of goods traffic. In its practical application, however, particulary when deciding how to allocate the receipts, it involves many drawbacks.

The Railways whose replies show they have adopted this system, at least for part of the through traffic *(Germany, Switzerland, Holland)* have not given any detailed information on the apportionment of receipts, and all we know is that it is in accordance with a scale agreed between the main-line and light railways. Apart from certain reductions allowed for policy reasons, the establishment of such scales must be based more or less closely on an equitable division according to which the share of each carrier is in proportion to the services rendered and therefore, as all the other factors are constants, to the distance worked. Though this system is just in theory, the light railways cannot look upon it with favour, because what is a just share is not always a remunerative one.

As the *German Railways* pointed out, such a way of dividing up the costs should not apply to the terminal expenses which should be divided equally between the two railways. There then remains the part of the rates which depends upon the length of the journey, which is the usual distinction made by main-line railways in all their rates. Consequently if the transport rate is divided up exactly in proportion to the mileage, the light railway will only receive a very small part as its share on account of the short

distances involved. The price it gets per unit of traffic in this way is always less than what it requires to make a profit, and the rates it has to charge for its own services, precisely because of the small amount of traffic and the short distances ; in other words the traffic cannot be considered profitable. Moreover, as the average basic rate is a direct function of the length of transport over the main-line railway, the receipts of the light railway, apart from exceptional cases, are uncertain and variable, which is naturally serious from many points of view and in many circumstances.

The railway, like all complicated undertakings, must of necessity reduce to the absolute minimum all incertitude in the essential details of its services ; consequently the already natural uncertainty about the kind and volume of traffic must not be aggravated by uncertainty about the rates, any reduction in which, especially if on a large scale, must be preceded by a proportionate reduction in the costs. Co-ordination of working may be a good way of adapting the costs to the present day marked tendency to lower the rates, but in our opinion an apparently closer co-ordination must not be achieved by upsetting the complicated and delicate foundations of secondary railways.

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Routing.

A question closely connected with the rates and the method of calculating them in through services is that of routing the traffic which, to safeguard conflicting private interests, must be carefully considered by both carriers when the light railway connects with the main line railway at two or several points.

Our enquiries showed that no Government has thought it legitimate to absolutely forbid agreements of this kind ; even when they are forbidden in general, as in Austria, the law itself provides exceptions likely to render it completely ineffective. This seems only just as a categorical interdiction would be contrary to transport economics.

A fairer rule, and one that is not contrary to the private or general interests in question, is that contained in the Italian law, according to which the operator of a public railway has the exclusive right to operate any other railway of any other kind serving the same places or joining up two places on the system by a shorter route. If regulations of this kind are of a general nature and thereby prove the foresight of the legislator and his paternal care not to interfere with existing rights, without stopping the development of the national railway system in the interests of the economic system of the country itself, transport undertakings already in existence who are not making use of this privilege, will nonetheless consider they have the right to endeavour in every way to keep the traffic they have already acquired. This right is derived from the generally admitted principle in the old railway legislation that, even in international services, every railway system has the right to work over its own lines such transports of goods as it can assure will arrive at destination, selecting the best route itself, even, it has sometimes been held, against the express wishes of the consignor. This principle appeared well founded in fact as long as the development of the railway was at full beat — with that type of operation in which the private economic coefficient was preponderating, to use the classic formula of Launhardt — for two reasons : *(a)* to avoid the construction of lines to carry solely or mainly traffic already provided for elsewhere, when the resources destined for the development of the means of communication should be spent on sections likely to give rise to new traffic where the inestimable benefits of mechanical transport were not

already available ; (*b*) to guarantee to the concession holder operating the line stability of receipts, so as to interest private capital in railway investments.

To-day, on the other hand, when the railways have attained the full development made possible by the undeniable progress of the last 50 years, and the evolution of the method of operation is more and more towards the public economic coefficient, and the railways no longer enjoy a monopoly, at least for certain classes of traffic, and have to struggle energetically to keep their position, the absolute application of this principle would seem no longer to meet the interests of railway carriers just as such an attitude no longer meets the interests of national economics.

This situation has already been recognised explicitely in certain countries. For example whereas as a general rule the traffic between two junction stations goes by the main-line railway, in Italy since the last general revision of the rates (November 1921) it is laid down that the traffic *between joint stations* must follow the most economical route, and to avoid undue influence of the staff of the operating company, no demands to the contrary can be entertained. A similar regulation applies to transport which, handed in at a common station for a destination beyond another common station can go over the lines of one carrier only or over those of both.

Without going into details, it may be said that in the countries where the utility and need for letting the public enjoy the considerable advantages of co-ordinated operation has been most strongly felt, so that the lines belonging to different railways look like a single system to the public, the old idea of keeping for the first railway all the traffic it could assure exclusively over its own lines has given way bit by bit to the idea of letting the transport benefit by the lowest possible rates, by working it by the most economic route, when such economy is not obtained at the expense of delays in transit.

The cases in which the *shortest route is preferred* are not rare. It should be pointed out that the main interest is considered to be the speeding up of the transport at the lowest possible rates, not overlooking the fact that the shortest route for through services is not always the most economical.

This was the point we alluded to at the beginning of this chapter when we said that the route question is closely bound up with the rating system and the method of calculating the costs.

When it is possible to adopt equal rates on railways in connection, and distances which are added up when applying the rates, the shortest distance is always the most economical. But, when for the reasons given above, it is not considered advisable to adopt this system, it frequently happens that when differential rates are applied on the separate distances the lowest total charge is often obtained over the longest route due to the sliding scale of rates being in force. This is certainly not to the advantage of the small railway system, but it undoubtedly gives the users a concrete and certain benefit.

Taking the shortest route as the criterion while being financially more advantageous for the light railways, should also give the public, at least the advantage of prompter delivery. But this is generally not the case, as the time saved by immediate connections, shorter and more direct route, etc... is always much less than that required for transhipping the goods from one railway to another. It would seem therefore, at least in the case of through traffic, i.e. traffic handed in at one railway for a destination on another, the object aimed at by sending the transport by the shortest route is made altogether illusory by the probable increase in the total carriage rates.

The position is the same, in our opinion, as regards traffic handed in to the main line railway for stations on the latter, when the shortest route involves using one of the lines of a light railway. In this case likewise, the postulate is that the mixed route should be more economical and faster. But as regards the cost, the arguments given above can be repeated ; in fact, in this case as well, lower charges could only be obtained by adopting the same rates and costs based on the added distances. If, on the contrary, the light railway's share according to its own rates is counted separately, even when the main-line railway consents to adding up the mileage of the two parts over its lines, in most such cases the public would have to pay more than the main-line railway would charge for working the whole transport over its own lines. What seems more serious is that this also affects prompt delivery, for obvious reasons when we remember the inevitable delays at the two junctions for transferring the goods from one railway to another, the time taken to do this usually being longer than the time required for the whole journey over the main-line railway.

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Common use of rolling stock.

From the point of view of co-ordination, the conditions regarding the use of rolling stock belonging to one railway by another railway are no less important than the questions examined above. Owing to the serious drawbacks, especially in goods traffic, of not allowing stock belonging to one railway to run over lines belonging to another, we think co-ordination between railways of the same gauge, without interchange of rolling stock completely insufficient. We are supported in this opinion by the information collected during the enquiries we made and note with satisfaction that : *(a)* in all countries there are agreements which have led to this very effective method of connection between different railways ; *(b)* this result has been obtained in spite of the fact that the carriers are not bound thereto by any legal obligations ; *(c)* there is a fairly large number of narrow-gauge railways which remedy the drawbacks inherent in their layout by the use of transporter trucks. In this way goods are carried from the junction station to destination in the same vehicles in which they were loaded at departure, which avoids all transhipment and also, at any rate as far as complete wagon loads are concerned, circumstantial and contradictory verifications.

Having said this, we might have considered our duty in this respect ended, as, unlike what occurs with legal and economic agreements, when it is question of measures leading to concrete facts, the forms and conditions take second place compared with the preponderating importance of their existence.

However, as we have already said, our investigations are intended to make the experience of each railway available for all, so that we should like to say a few words on a few details practice has shown to be of value in order to achieve this important element of co-ordination.

Agreements about the circulation (interchange) of goods wagons can be considered as based on two main systems, which in principle differ very little from each other.

The first of these two principles, put into practice in Germany by the *Rolling Stock Union* and adopted in Switzerland by the *Swiss Association of Goods Vehicles*, involves the common use of the rolling stock of all the railways. Each secondary railway belonging to the Association registers with the main-line railway a sufficient number of wagons to meet the requirements of its traffic. The main-line railway uses these wagons as

its own, and also provides for the needs of the secondary railway by means of its own wagons. Consequently no reciprocal charges are made for the hire of wagons ; only when it is found over an agreed period that the wagons of the secondary railway have been used excessively by the main-line railway does the latter pay the owner an indemnity fixed beforehand. In the same way, the secondary railway pays the main-line railway when it makes excessive use of the latter's wagons.

This common use system undoubtedly makes it much easier to exchange traffic between the railways and, therefore, must be considered most effective as regards co-ordination. It is based financially on compensations in kind, with monetary payment only for additional services. We do not know, however, how the railways belonging to the associations settle and distribute the costs of maintenance and repair of the stock. On the other hand, it appears that in other countries where endeavours were made to come to such an agreement, good results were not obtained owing to the many delicate questions in connection with the subjects just mentioned. Actually the secondary railways have found too costly the repairs carried out on their behalf by the main line railway which, to avoid duplication, has to be entrusted with these operations for the common user scheme. On the other hand, the main-line railway has no basis of calculation for such compensations, nor for those of other operations carried out if it does not start from its own cost price.

Difficult though not insoluble questions also arise in the case of the other most used system based on the exchange and reciprocal use of goods wagons against hire charges. The computation of these latter, and the fixing of the beginning and end of the period of use are the subject of great disagreement between the secondary and main-line railways where this system is used, as also when the main line-stock alone passes unto the secondary railway. Possibly the important interests at stake have overcome these difficulties, which are only financial and have nothing to do with the technicalities of co-ordination.

As regards passenger services by through coaches, in the few cases where regular exchange services are run, this is done by special agreements based on compensations in kind, whereas when odd vehicles are exchanged for exceptional services special agreements regulate the exchange conditions.

From the co-ordination point of view, we consider of greater interest for the trains to run over sections of one railway unto another, usually the main-line, in the place of an equal number of the latter's local trains or as a supplement thereto. This is a case of more intimate collaboration that might be thought to lie outside the normal field of co-ordination. We do not consider this a reason for neglecting it ; an organisation of this kind is in the interest of the public as well as that of the two railways, and we can therefore take the initiative of recommending an investigation into this subject in connection with the special local conditions. We have moreover to recognise that this is the reason why this question cannot be dealt with on broad lines.

Agreements of this kind usually depend on actual facts. When savings, by the railway which allows rolling stock to continue its route over its lines, are effected by suppressing certain of its own trains, it gets the receipts for the section and pays the other railway the cost of traction, rolling stock, and train staff used on the through trains. In other words, the owning system shoulders the hazards and overhead expenditure relating to the service.

On the other hand, when the stock is worked forward for the benefit of the railway running the trains, with little or no saving for the other railway, the

owner of the line proportionally recovers the permanent way and station costs from the receipts, and leaves the rest of the train receipts for the railway working them.

* * *

Containers.

The services recently instituted by some of the main-line railways by means of the equipment now generally known by their English name, *containers*, are considered of great value in co-ordinated operation, especially between railways of different gauges. From a wider and more general point of view, this question is still the object of experiments and investigations. The results obtained in various places, the inherent possibilities of this system, and the real utility it offers for certain traffic make us think that the use thereof will be developed in the near future and become ordinary practice in railway working.

* * *

III. — Accessory operating conditions.

Road competition.

This review of the fundamental bases of co-ordination between main-line and secondary railways, as it exists in fact and as it could develop owing to the tendency towards improvement noted above has, we must admit, certain defects and many gaps, and doubtless others will be found by those who have followed the present report.

Although limiting ourselves to co-ordination between the railways of a given country as a normal phenomenon of railway life, we cannot refrain from considering the new method of transport which, as someone has said, « brings in the acrimony of the competitor with its bitter odour of petrol and bitumen ».

This new method, which is undoubtedly a new force in the transport industry, in the last ten years has reached unexpected limits and is always progressing, has profoundly upset transport economics, and consequently just as it was not and could not be neglected by the general technique of railway working, cannot and ought not to be neglected when the technique of co-ordination is considered.

It is not our business to examine what has been or could be done by the Government to restrain within suitable limits, we would even say within the limits meeting the interests of the general economic system, the competition of the new mechanical method of road transport. We do not wish to see if the competent authorities have eliminated the very flagrant differences of treatment that are so harmful for the railway. We ask, however, if and to what point provision has been made for applying to the competing method of transport the many legal requirements which oblige the railways, in the interests of third parties, to accept goods, to publish their rates, to look after the safety of passengers and goods, to respect the contracts, the police and hygiene regulations, and, in the interests of the State, the financial regulations, all of which lead to very heavy expenditure.

We could have wished that, like those of *Hungary* and *Jugoslavia*, all the railways could reply to this question : « Competition between road and rail is finished ; the steps taken by the law are sufficient ». We would have been happy to have echoed such an agreement.

Unfortunately these two voices remain isolated in the general chorus, which has been obliged to admit the inadequacy of the measures taken by the higher authorities.

These voices, however, seem to represent a promise for the future, as they show that ending the struggle is no utopia.

Doubtless, in the troubled period through which world economics have

passed, which cannot yet be considered as having completed its cycle, too many antagonistic elements have arisen simultaneously for every difficult problem to be solved everywhere. We think it certain however, that with a return to normal of all economic functions, after eliminating the factors and effects due to the crisis, under the impulsion of the railways' requirements, particularly of the secondary railways, proper steps will be taken immediately.

On the other hand, if the assistance justly due to the railways, and in the true interests of the country, is delayed, the railways themselves cannot and ought not to remain inactive.

What the railways have to do and have already done is little in comparison to what ought to be done ; we think therefore that nothing should be neglected by the railways to stimulate the slow initiatives of the higher authorities, so that they can speak with assurance, satisfied they have done everything possible.

It is true that the new method of transport has very largely profited from the general state of semi-indiscipline according to which old out-of-date vehicles were allowed to run without restriction on the road. Indeed, the newcomer, powerful from birth, was able to establish itself in the middle of the general surprise, it might almost be said the general scepticism. It must not be gainsaid that many of the factors of success, probably the most important, were part of its very nature, and it was precisely these elements which made the railways themselves look upon the new transport as an undoubted improvement in the field in which it competes, since it has advantages the railway can never completely offer by itself. This does not mean, however, that the railways cannot make a great step in this direction and this is the object they should always keep in view. It is a question as a rule of improvements which do not modify in any way the henceforth solid structure of railway working which, during its long life, has shown such strength and possibilities that we consider it capable of unlimited development in its own field of action.

This seems possible for certain details of our systems, the improvement or reorganisation of which can offer the public at least some of the characteristic advantages of road transport. What will still be lacking for the public will be largely made up by the other and greater advantages the railway can offer.

We will add to these general considerations a few remarks about special questions closely attached to our report on co-ordination.

* * *

Transport acceleration.

As regards the average running speed, the railways have already made a great effort ; it is the same with the more or less general use of light trains, and in this connection we do not think they can be much improved. We cannot say as much as regards the overall speed, on account of the frequent stops, the unavoidable shunting at junctions, and, still more, the transhipments and handling of small consignments.

Serious efforts have been made by the main-line railways to extend the specialisation of fast trains over suitable routes, so as to reduce to the minimum compatible with the remunerative use of the stock, the weight laid down for combined loads, over routes agreed beforehand. This system cannot be used for exchange traffic between main-line and secondary railways ; to speed up this traffic it is necessary to reduce to the minimum the stops at junctions, so that the unavoidable delays may be better employed, as Mr. L. Jacobs, the Reporter on the same question at the Cairo Session, recommended, by using for transhipping the most appropriate means and methods, doing away whenever possible with long and costly manual handling, for all the accessory operations which should be carried out at the ex-

change points by the staff and mechanical equipment (weighbridges, cranes, etc.) of the main-line railway. The charges for the use of such equipment should not cost the latter too much.

* * *

Accessory services.

The lorry's characteristic advantage is that it is self-contained. In comparison with the services rendered by the railway — we are sure we are saying nothing new or anything which has escaped the general notice — the source and cause of great difficulties, especially from the point of view of safety of the passengers and goods carried, this advantage makes the road motor a complete service which the railway cannot be without having recourse to certain expedients.

Door-to-door services from departure to destination are of considerable importance, for luggage as well as for goods. The railways of all countries have taken this into account and have introduced door-to-door services on a large scale as a means of meeting competition. As a rule these services are limited to luggage and small parcels, and only between large and medium-sized centres. Only a small proportion of the secondary railways have introduced such services.

We understand that technical and financial difficulties prevent the unlimited extension of these services ; but we think that a passive attitude towards them will cause great prejudice, especially to secondary railways, which are the most seriously threatened by competition. Consequently, we are of the opinion that when properly combined with the use of other means under test, i.e. the container dealt with above, these services can be largely applied to goods in complete loads and to goods of comparatively high value.

* * *

Reducing expenditure and simplifying the accounts.

As any factor which has any direct or indirect effects on « production » or which is connected therewith has to be subjected to the laws thereof, the creation and the development of means of communication are dominated by the « cost price » factor.

Undoubtedly one of the principal factors of the victorious progress of our competitor must be looked for precisely in his lower rates, especially for valuable goods, which naturally he selects in preference to the others. This fact is due partly to the unrestricted way in which he has been allowed to develop, which has enabled him, as we have already said, to effect serious economies; but we think the most important causes are the lower costs under equal conditions of the basic factors on which he depends (family working, door-to-door transport, maximum use of stock, return loads) and the natural possibility of adopting a very simple organisation, the cost of which can be reduced to the minimum compatible with the existence of the undertaking.

Nothing or at least very little can be done to make railway conditions approach the first two conditions ; on the other hand, we do not think everything possible has been done as regards the last point, by reducing the expenses in the details of the railway services, especially in the field assigned to our examination of the co-ordination of operation.

This investigation, limited to the technique of co-ordination, does not allow us to make a deep study in connection with the opinion expressed above as this would involve considerations of a definitely financial nature. But amongst those who devote their daily activities to this question, there is no one who does not see the frequent cases in which the

various methods adopted by the different railways for service details with the same object and consequently not differing in their practical application except in form, require each operator to carry out the same operations for himself with a loss of time and double expenditure which could be avoided with a little ingenuity.

A typical example is the way the accounts are got out and the revision and clearing of accounts in connection with the exchange of traffic in the joint services.

It is true that the replies received on the questions about this matter did not enable us to get any exact idea of the different systems described in broad lines in these replies ; for this reason, we have no intention of criticising the systems used which, we must admit, meet the particular requirements of the railways and show accurately and clearly the financial situation of each carrier.

Our general impression, however, is that, as a rule, even where an endeavour is made to reduce the accountancy work to a minimum, as in Germany, Austria and Switzerland, further important simplifications and economies could be made if the accounting methods, including checking and paying, were confided to a single office for all the railways working together in co-ordination, i.e. with the single exception of the services we have called « correspondence » services for which the debit and credit accounts are got out in the exchange stations.

Without speaking of the British « Railway Clearing House » which has much greater authority, an office of the kind known as « Common Control », the name of which does not bring out its whole field of responsibility, works in Italy to the satisfaction of the main-line railway and all the light railways belonging to the organisation.

By means of the documents from the departure and arrival stations, belonging either to the main-line or the secondary railways, this office makes all checks, as regards the regularity of operations, as well as the amounts recovered from the public. Mistakes made by the staff are corrected by the Office through the railways to which the employees belong, and through the stations affected ; provision is also made for the supplementary recovery of money in the case of insufficient charges and for settling claims. Finally, the Office acts for all member carriers as a « compensation house » drawing up within a maximum period of two months the credit and debit balances for all parties concerned.

This institution, which has been working in Italy for about 15 years, was mainly inspired by a desire to simplify and eliminate the accountancy offices at the junction stations and the many small clearing offices on the secondary railways. Consequently it is a far from negligible source of savings on the expenditure of all member railways, particularly the secondary railways which are debited in proportion to the number of transports they are interested in, with half the staff charges, while the main-line which operates the common office on the same lines as its own offices pays the other half of the cost of the staff and all the general charges in connection with the installation (offices, maintenance, lighting, heating, etc.).

* * *

CONCLUSIONS.

As we expected our investigations have revealed nothing really new owing to the conditions and systems which have been developing and strengthening their position for the last ten years. We have come to the following conclusions based on the present state of co-ordination and its future possibilities, taking into account the possibilities of the critical times through which we are passing :

1. In all countries, co-ordination of operation of the main-line and secondary railways is recognised, in principle, as not only useful, but vital in the general interest.

2. It is generally considered as an effective means of meeting the growing competition of other more modern methods of transport.

With particular regard to the *installations :*

3. In the case of two railways of the same gauge, it is preferable to have common junction stations in which the existing equipment of the main-line railways is used to cover all the needs of the secondary railway.

4. In the case of railways of different gauges, with separate stations near one another, the narrow-gauge line should run into the main-line railway station, unless transporter trucks are used ; in this case it is desirable that the connection should be a standard-gauge line.

As regards *operation :*

5. Both in joint stations and in separate stations connected together, the main-line railway should co-operate with the light railway to the maximum possible extent, in return for suitable compensation.

6. Through (interchange) traffic should be dealt with under a combined-service system, with a single transport contract (waybill) and joint responsibility of the carriers.

7. When a combined service is impossible or inconvenient, the carriers should make agreements about correspondence services for carrying goods without intermediaries at the junctions, fixing according to the best interests of the users the limits of responsibility and competency of each carrier, administratively and legally.

8. It is desirable that the carriers should control their own rates and on the basis of these rates, each carrier should receive the amount due for the services actually carried out on his line.

9. It is always better for through transport to follow the cheapest route, unless this seriously interferes with prompt delivery.

10. It is not desirable in principle to enforce transit in the case of through traffic, even when the transit route is the shortest.

11. When common stock and the indiscriminate use of goods wagons are not considered advantageous, railways of the same gauge, provided safety is not affected, should make agreements for the reciprocal exchange of goods wagons, or at least for running main-line vehicles over the secondary railway.

12. In the case of narrow-gauge railways, transporter trucks or containers meet the difference in gauge very effectively.

13. In the case of passenger services, connecting the light railway with important centres on the main-line railways by means of trains continuing over sections of the main-line can be tried with profit.

As regards *competition,* conjointly with the more important means investigated by the technical services to get the best out of co-ordination, the following can be recommended :

14. The main-line railway should co-operate to the maximum extent in increasing the average speed of goods in through traffic.

15. The greatest possible extension should be given by both the main-line and secondary railways, to accessory services giving door-to-door transport.

16. Whilst safeguarding the autonomous organisation of each railway, the accountancy work should be simplified as far as possible and the particular branches of the services should be combined in order to eliminate duplication.

[625. 17]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

13th SESSION (PARIS, 1937).

QUESTION III.

Methodical and periodical maintenance of : 1. metal bridges; 2. signals; 3. metal supports carrying the contact wire on electric railways.

Organisation. — Working methods. — Materials used.

REPORT

(Bulgaria, Egypt, Spain, France and Colonies, Greece, Italy, Portugal and Colonies, Rumania, Czechoslovakia, Turkey and Jugoslavia),

by V. DEGREEF,

Ingénieur au Service de la Voie de la Société Nationale des Chemins de fer belges.

The questionnaire relating to this subject was sent to thirty Railway Administrations. Replies were received from the 21 Railways named below; however, some of the Administrations only replied to Part I of the Question.

1. Bulgarian State Railways.
2. Egyptian State Railways.
3. French State Railways.
4. Hellenic State Railways.
5. Italian State Railways.
6. Rumanian State Railways.
7. Czechoslovak State Railways.
8. Turkish State Railways.
9. Jugoslav State Railways.
10. Algerian Railways Company.
11. French Est Railways.
12. Paris-Orléans—Midi Railways (1).
13. French Nord Railway.
14. Paris - Lyon - Méditerranée Railways (P. L. M.).
15. Alsace-Lorraine Railways and Guillaume-Luxembourg Lines.
16. Portuguese Railways Company.
17. Compagnie française des Chemins de fer de l'Indo-Chine et du Yunnan.
18. Damas-Hamah Railway and Extension.
19. Compagnie du Chemin franco-éthiopien de Djibouti à Addis-Abeba.
20. Société Générale des Chemins de fer économiques, Paris.
21. French West-Africa Railways.

The following Administrations informed the Reporter that they could not supply any interesting information on Question III, as this subject had been little investigated by them.

Railways in the Portuguese Colonies;

(1) Joint working of *Paris-Orléans Railway and Midi Railway.*

National Railways Company, Lisbon ; Anzin Railway (France); Chemins de fer secondaires du Nord-Est (France); Tunisian Railways ; Compagnie des Phosphates et du Chemin de fer de Gafsa; Compagnie des Chemins de fer du Maroc; Nord-Milano Railway.

1. — Methodical and periodical maintenance of metal bridges.

The Chief Civil Engineer on most railways is responsible for new construction and maintenance.

On the *French Nord Railway,* the Chief Engineer has under his orders a section known as the Permanent Way Equipment Designs Office, which designs the metal bridges, prepares the specifications and inspects the work in the contractor's shops and on the line. This service also exercises a special control over all structures on the railway. The maintenance engineers are responsible for the erection of new structures and their maintenance.

On the *Italian State* Rys., as on the *Turkish State Rys.,* the construction of new lines is dealt with by a special department of the Ministry of Public Works.

On the *Rumanian State Rys.* there are two distinct organisations, one dealing with maintenance, and the other with new constructions (lines, structures, and large buildings), and the *Bulgarian State Rys.* have at Headquarters a section for dealing with the construction of new lines and another for maintaining existing lines.

On the *Jugoslav State Rys.* new lines are dealt with by a special department until they are completed, after which they are handed over to the Permanent Way Department.

As regards the *Algerian Rys.,* new lines are built by the Railway Building Department for the Colony, a department which comes under the Governor General of Algeria.

On all Railways, large and medium, the whole of the lines are divided for maintenance purposes into divisions which are further subdivided into districts and sections.

The following table gives, for the most important Railways the length of lines in the divisions and sections :

TABLE I.

Railway.	Total length of system in km.	Length of the divisions.	Length of the sections.
Bulgarian State . . .	2 794 km. standard gauge and 419 km. narrow gauge, in all 3 213 km.	12 maintenance sections of 270 km. on the average.	
Italian State.	16 297 km.	1 250 km.	100 km.
Rumanian State . . .	15 350 km., of which 11 590 km. main lines.	10 divisions of 1 500 km. on the average.	200 km. on the average
Czechoslovak State . .	13 500 km.	2 000 km.	100 km.
Turkish State	6 000 km.	Operating divisions of an average length of 700 km.	150 km.

Railway.	Total length of system in km.	Length of the divisions.	Length of the sections.
Jugoslav State	7 109 km. standard gauge; 1 882 km. 0.76-m. gauge; 379 km. 0.60-m. gauge; Total : 9 370 km.	5 divisions of 1 880 km.	155 km.
Portuguese Rys. . . .	2 474 km.	13 sections of 190 km.	
Alsace-Lorraine Rys. . .	2 120 km.	3 divisions of 700 km.	From 65 to 195 km.
P.O.-Midi	11 400 km.	1 200 km.	200 km.
P.L.M.	9 950 km.	400 to 1 300 km.	80 to 260 km.
French Est	5 132 km.	730 km. on the average.	120 km.
French State	9 000 route-km. (13 000 track-km.).	1 400 track-kilometres.	150 track-kilometres.
French Nord.	3 922 route-km. (6 550 track-km.)	560 route-km.	100 route-km.
Algerian Rys.	4 830 km.	1 610 km.	220 km.
Egyptian State. . . .	3 795 km.	4 divisions of 950 km.	10 sections.

This table shows that the length of the divisions is from 560 to 2 000 km. (348 to 1 240 miles), and that of the sections from 65 to 260 km. (40.4 to 162 miles).

As a rule, the inspector responsible for permanent way work is required to report any defects observed in metal bridges. The inspection of metal structures is, however, often dealt with by a special organisation.

P.L.M. Rys. — A permanent way inspector is specially entrusted with the examination of metal bridges when his assistance is required by the local service normally responsible for this work.

French Nord. — The maintenance engineers are responsible for reporting any defects in the bridges and for putting forward suggestions for repairing them. The designs office draws up a repair plan and the instructions for carrying out the work.

French Indo-China & Yunnan Rys. Co. — An engineer specialised in metal structures is employed and is responsible for the maintenance of the steel bridges; he comes under the local section as repairs to the bridges are taken in hand.

Rumanian State. — The whole of the metal bridges are periodically inspected with great care every five years by special inspection gangs under a specialist and under the general control of the local maintenance engineers. Each division has an inspection gang of this kind.

Bulgarian State. — The maintenance

of metal bridges is the task of a special technical section.

Jugoslav State. — A special section (three shops) is responsible for examining and repairing all the metal bridges of the division.

The *Turkish State Rys.* employ four engineers whose sole task is the inspection of metal bridges.

Movable bridges.

In most cases the permanent-way engineer is responsible for the maintenance of the movable bridges. On the *P.L.M.*, the mechanical engineer is responsible for this work so far as the mechanical part is concerned.

None of the Railway Companies with which we are dealing report the use of roller bearings on swing bridges or drawbridges.

Periodical examination of bridges.

This varies considerably from one country to another. However, an annual examination with a thorough inspection every five years, is the method most resorted to.

French Companies (including Colonies). — An Annual examination, usually carried out by the head of the section.

Quite apart from this examination, the metal bridges, as required by law, are inspected in detail once every five years when the permanent deflections are measured in the presence of one of the inspecting engineers of the State. In the case of bridges supported at both ends, the level of the buttresses is checked. On the *French Nord* the bridges are inspected in addition by an official in the permanent way designing office, in the year before the quinquennial inspection.

On the *Italian State Rys.* the important parts of the bridges are examined each year, and every six years the whole of the structure is inspected in detail.

The *Bulgarian State* and the *Portuguese Rys. Co.* carry out an annual examination as regards the rivetting, the condition of the various parts and of the paint.

Bridge painting.

Frequency.

The interval between repainting varies considerably according to country and climate. On the average it is five to six years. However, some Railways, such as the *Czechoslovak State,* report a period of about 10 years between the application of the last coat of paint and the next repainting.

The *Italian State Rys.* report varying intervals, 8 to 10 years, on bridges in dry districts, and 2 to 3 years near the sea.

The *Algerian Rys.* repaint every five years with ordinary paint, and 6 to 8 years when metal paints are used.

Painting methods.

The most usual practice is to clean and repaint by hand, although mechanical methods (pneumatic or electric cleaning tools, and spray painting) are used by a few railways, usually experimentally. The *French State* admits spray painting for the final coats.

The following railways : *Italian State, Turkish State,* (on large bridges only), the *Czechoslovak State, Portuguese Rys. Co., French Nord* and *State,* are carrying out experiments in this direction.

The following questions have been asked :

1. Do you find spray painting cheaper than painting by hand?

2. Do you find spray painting as satisfactory as hand painting?

Opinions are divided.

The *French Est* reports that spray

paint has not stood up well in very damp places.

The *French State* considers the work much less satisfactory for the first coats, and reports considerable paint losses due to the wind and the openings in trellis girders, so that the method has not been continued. In addition there was no appreciable reduction in the contract prices.

The *Turkish State* and *Portuguese Rys. Co.* consider, especially in the case of large bridges, that spray painting is the cheaper method.

Painting materials and number of coats.

In the case of new bridges, one or two coats of red lead and two coats of white lead, zinc white or special anti-rust paint is the usual practice.

The composition of the paint used by the *French Nord* as specified by their laboratory is as follows :

Micaceous iron	60 %
Graphite	6 %
Boiled linseed oil with lead and manganese	31 %
Turpentine (white spirit not allowed).	3 %

The *Franco-Ethiopian Ry.* is satisfied to give two coats of tar in the case of bridges of 4 m. (13′) span or less.

In the case of existing bridges, the general rule is to scrape all rusted or otherwise damaged places, wash the whole surface and afterwards apply one or two coats of red lead on the derusted surfaces and finally two coats of paint over the whole of the structure.

The following question was asked :

When repainting a bridge, do you repaint surfaces the paint of which is in good order?

The answer was in the affirmative, except in the case of the *French Railways* and the *Damas-Hamah Ry.*

A number of Companies report, however, that only one coat of paint is given to surfaces where the paint is in good condition, for example the *Egyptian State Rys.*

Cleaning the structure.

In the case of existing bridges, rust is usually removed by hand. Sand blasting is used by some Companies on much rusted bridges, and the operation is continued until all scale is well removed.

None of the countries with which we are dealing reports the use of special steels.

In South-Eastern Europe and the Colonies, the work is done by the railways themselves. The *French Railways,* especially for large bridges, contract out the derusting and repainting work. The *Italian State Rys.* contract out the work, the paint being supplied by the railway.

The first coat of paint is applied immediately after the rust has been removed and the red lead applied.

In the case of bridges on electrified lines, the current is cut off between two substations (either at night, or between certain trains), but as a rule only when the work is carried out within 3 m. (9′10″) of the conductors. As a rule portable earthing devices are used on contact lines not under tension on both sides of the section being painted. On the P.L.M., the substation is not allowed under any circumstances to restore current before receiving a written demand, and notices inscribed « not to be moved — work in progress on the line » are hung on the switches.

Repairs of metal bridges.

Small repairs are usually carried out by the ordinary staff. Railways having special gangs for inspecting and maintaining bridges prefer to do the work themselves, even in the case of heavy repairs.

Some of the railways report that they make use of the workmen and the tool

equipment belonging to the mechanical engineer's department.

Pneumatic tools and electric welding are in ordinary use, especially for work of some importance. The *French State* requires this equipment to be used by contractors. Most of the companies favour coated electrodes. The use of special apparatus (X-ray for example) for checking the welds has not been reported.

Strengthening bridges.

The strengthening of plain web girders is carried out by riveting diagonals on the web or by adding stiffening angles. A plain web girder has been strengthened by embedding it in reinforced concrete on the *French Nord.*

The trellis girder is usually strengthened by adding rolled sections, which are either welded or riveted into position. In this respect, an interesting example of strengthened trellis girder bridge has been reported by the *Jugoslav State Rys.* that of the bridge over the Neretva near Gabela (fig. 1) by means of welded sections.

A classic method of reinforcing the connections of the girders with the cross girders is to add an upper and lower gusset plate at the joints.

Several railways have reinforced the joints of the diagonals with the main girders by increasing the diameter of the rivets or by adding cover plates to make the rivets work in double shear.

Large metal bridges.

From the information supplied, the railways do not possess any special organisation or method for derusting, repainting, and repairing such bridges.

When pneumatic tools are employed, a portable compressor is used, or a compressed-air main is fitted the whole length of the bridge, and if the length of the bridge is enough to justify it, this pipe line is divided into two halves fed by the same compressor from each end of the bridge in turn.

On the Maria-Pia Bridge (fig. 2) over the Douro near Oporto (Portuguese Rys.) permanent equipment for inspecting and painting is provided at vital points of the structure, notably at the connection of the arch and the pillars. A permanent arrangement for erecting and moving scaffolding, provided to make it easier to repaint and inspect the structure, is fitted on the bridge over the Danube on the Belgrade-Pantchevo line (total length 1 525 m. = 5 000′). An inspection car is provided on the Eauplet Viaduct over the Seine near Rouen (343 m. = 1 125 long, fig. 2*bis*).

In the case of the Garabit Viaduct (fig. 3) and the Viaur Viaduct (figs 4 and 5) *(P.O.-Midi Rys.)* gangways and inspection ladders facilitate inspection of the different parts of the structure.

Some Companies use guard nets as a safety precaution when repainting large bridges. This is the practice on the bridge on the Yunnan line (French Indo-China & Yunnan Rys.) shown in figure 6. This bridge is 110 m. (360′) above the ravine.

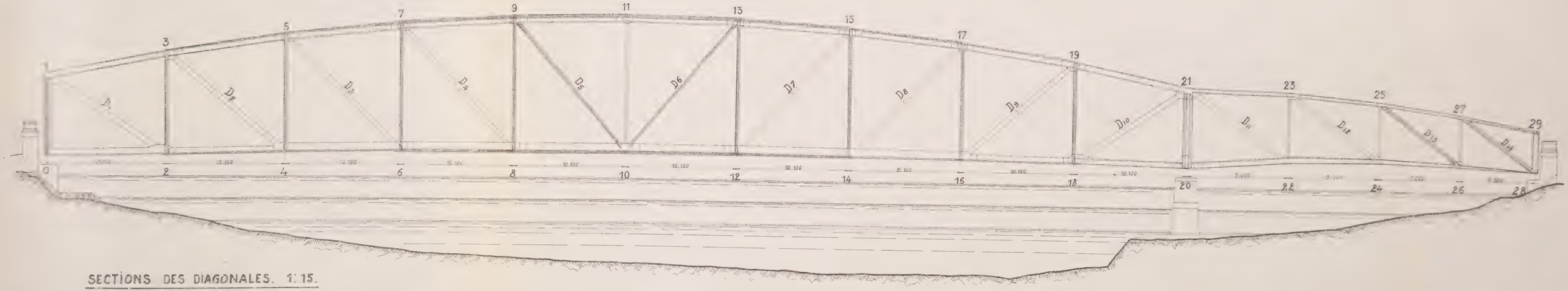
Flooring.

Under-bridges. — The usual type of decking is the wood floor with checkered plates between the rails. Some railways prefer smooth plates, as checkered plates hold the water. In the case of recent bridges the use of reinforced concrete slabs and cross beams is becoming more and more general, and when the available height does not prevent it, floors consisting of girders embedded in concrete with the track carried on ballast is preferred.

Over-bridges. — In old structures, wood flooring and brick arch flooring are usual practice.

The new bridges are built with con-

General view.



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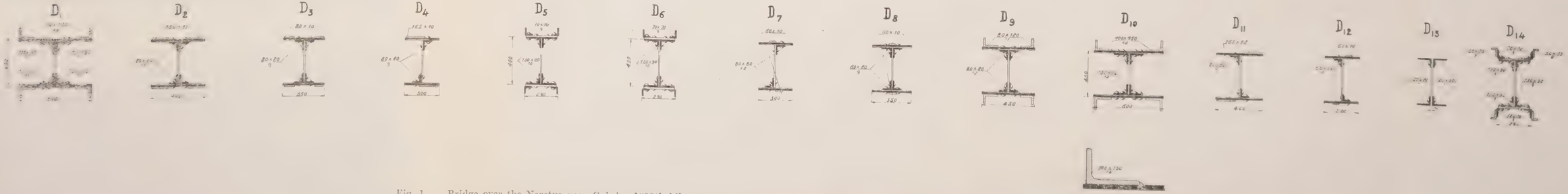

Fig. 1. — Bridge over the Neretva near Gabela, 1890th kilometre post of the Gabela-Dubrovnik-line. — Scheme for strengthening the structure *(Jugoslav State Railways)*.

Note. — The strenghtening parts on the sections of the diagonals are hatched.

Fig. 1 *(contd.)*. — Details.

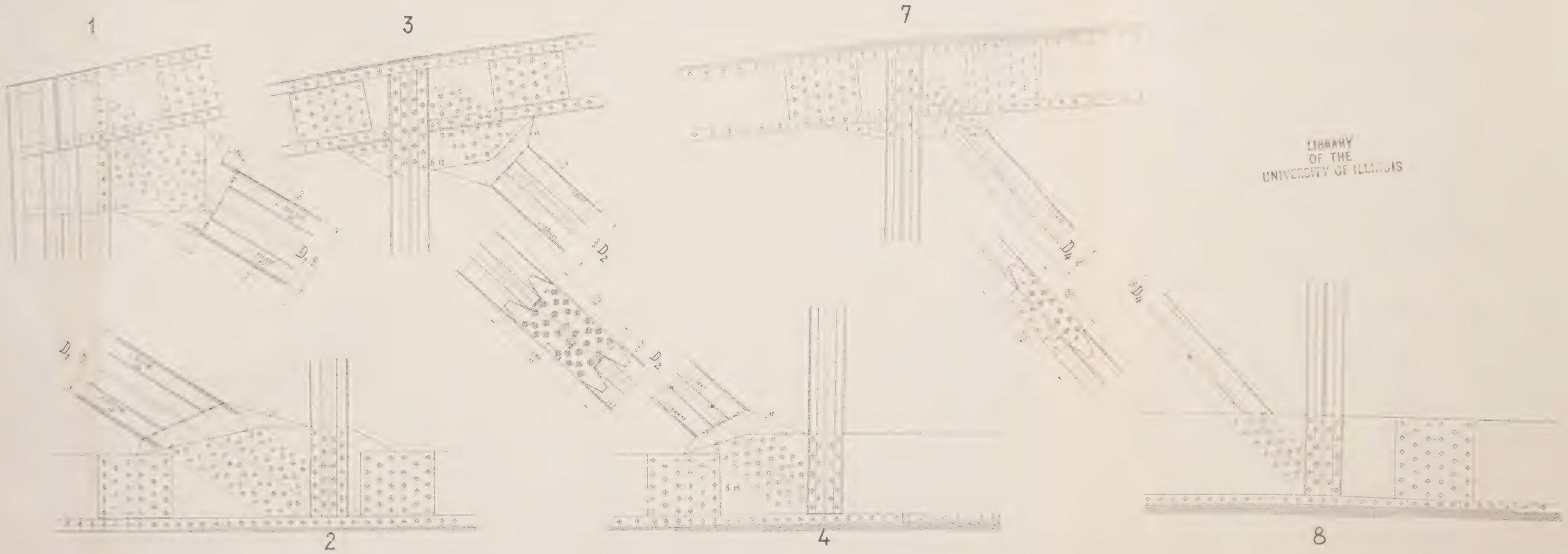

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Fig. 2. — Maria-Pia bridge over the Douro *(Portuguese Rys. Co.)*.

Fig. 2*b*. — Eauplet viaduct *(French State Rys.)*.

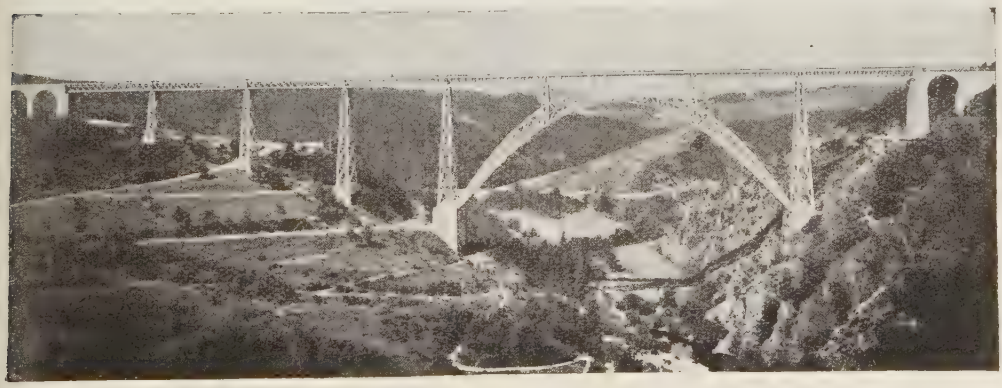


Fig. 3. — Garabit viaduct *(Paris-Orléans Ry.)*.

Fig. 4.

Fig. 5.

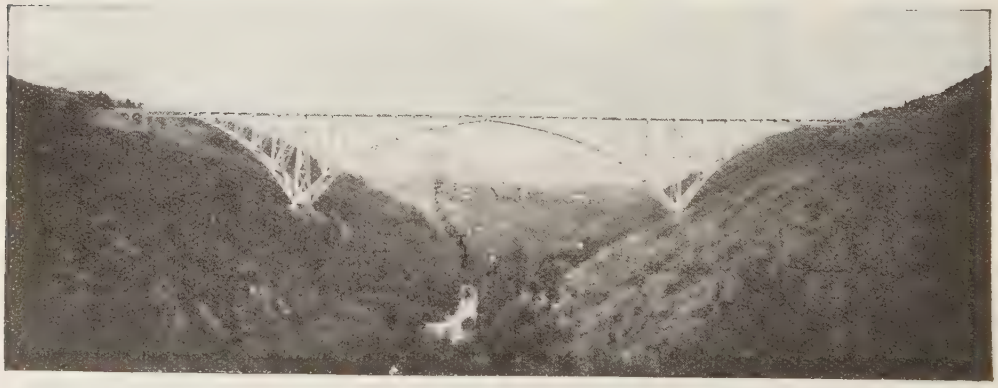


Fig. 4 and 5. — Viaur viaduct *(Paris-Orléans Ry.)*.

crete or reinforced concrete arches, the lower parts of the metal cross beams being embedded in concrete. In the case of new over-bridges, reinforced concrete superstructures are preferred as a rule.

Protection of the lower members of girders against weather and smoke.

Smoke generally attacks the lower parts of over-bridges on tracks on rising gradients, in stations, above shunting si-

Fig. 6. — Bridge on the Yunnan line *(Indo-China and Yunnan Rys. Co.)*.

dings (where the trains stand and start frequently) and protection by paint alone is ineffective. Painting is frequently done in such cases under difficult conditions.

Most of the Railways consulted fit wood troughs on steel frames above the tracks, or throughs made of sheet steel or fibro-cement which can easily be taken down. The *P.L.M.* reports, however, that the use of fibro-cement or reinforced concrete smoke troughs has not always been satisfactory.

The *French Rys.* are now considering the use of smoke troughs in rustless steel (copper bearing steel, Armco, steel, Apso steel, etc.) (See arrangements with the fastenings, fig. 7, according to information supplied by the Railways).

The *Algerian Rys.* use bitumen paint in order to protect such parts of the main girders.

Tests of protecting the lower parts of metal structures by using the cement-gun have also been carried out by some railways, but everywhere with disappointing results (insufficient adhesion, cracks, and the sprayed-on material falling away).

The *French Nord Ry,* reports an investigation into the protection of the lower parts of metal structures against smoke (1).

We give below an extract from the very interesting information relative to special protection devices, contained therein.

1. *Embedding.*

(a) *Embedding in reinforced concrete.* — The *French Rys.* have for some time been embedding in reinforced concrete the parts

(1) This investigation was made by one of the *Nord Railway* engineers, Mr. Widmann, for the recent Congress of the International Association for Bridges and Framework.

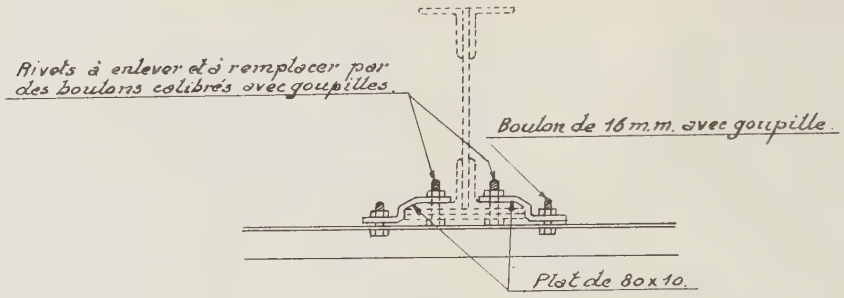


Fig. 7.

Note. — Rivets à enlever.... = Rivets to be removed and replaced by calibrated bolts with split pins. Boulon de 16 mm. avec goupilles = 16 mm. bolt. with split pin. Plat de 80 × 10 = 80 × 10 mm. flat.

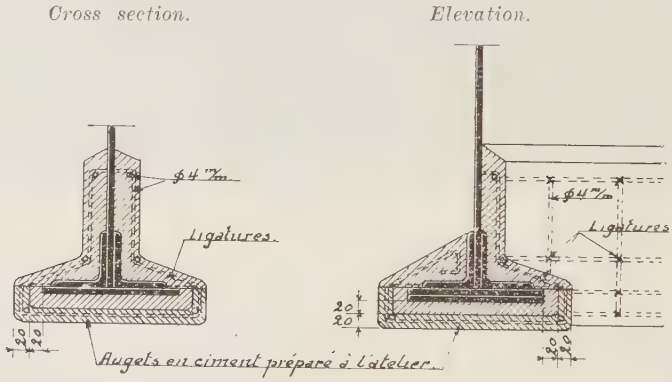


Fig. 8. — Method of encasing the lower parts of the framework of metal bridges.

Note. — (1) This method can be applied, on principle, to longitudinal girders, cross beams, struts, details made of plates, angles, flanges. The drawing in particular represents an assembly of braces and end girder.

(2) Ligatures = Binding wire. — Auges.... Precast cement troughs.

of the structures directly subjected to smoke from the locomotives. Such coatings should have a plane surface which will enable the smoke to get away quickly.

One frequently used constructional method is as follows (fig. 8) : Carefully made reinforced concrete troughs are got ready and filled with plastic mortar and then clamped up against the lower flanges of the main members until the mortar is set; gutters in cement are made between these troughs and the side faces of the members.

The reinforcement of the troughs should be hooked into the structure as securely as possible. In certain cases it is carried through the web.

This method of protection is completely effective provided it is properly carried out (cases of defective adhesion have been noticed on railway bridges when the work was done whilst the bridge was in use). Exploratory drillings in coverings made more

than thirty years ago over lines carrying heavy traffic, only a few centimetres from the top of the locomotive chimney, showed that the metal to be protected had remained untouched. This was also the case with the concrete and the reinforcement of the troughs (fig. 8).

The only drawbacks of this method of embedding are : The cost is relatively high, though it is balanced by the structures being perfectly preserved, and the cost of painting being saved;

The weight increases the dead weight of the bridge;

Its thickness (0.04 to 0.05 m. = 1 9/16 to 2") reduces the clear height.

On certain recent metal bridges, an overall raft in reinforced concrete carrying the roadway or the ballast encases the whole of the lower part of the bridges (cross mem-

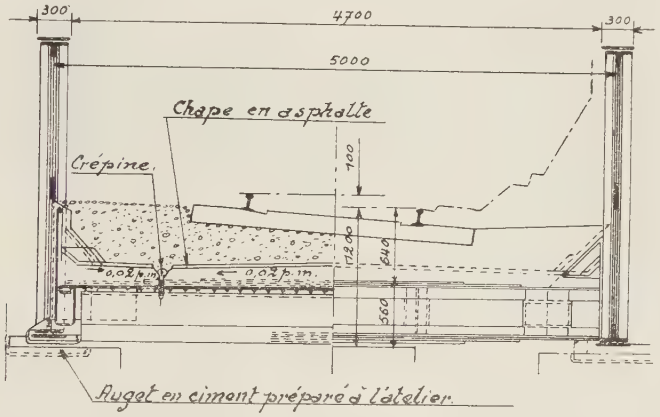


Fig. 9. — Cross section.

Note. — Chape en asphalte = Asphalt lining.

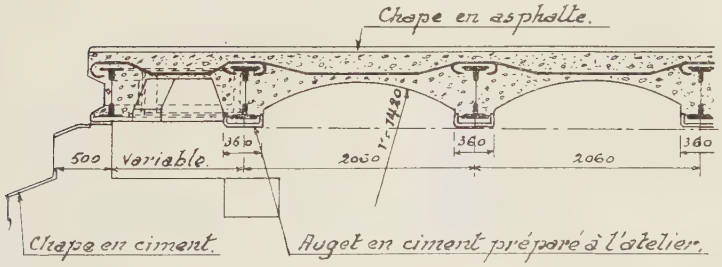


Fig. 10. — Longitudinal section.

bers and lower booms of the girders). Figures 9 and 10 show an under-bridge of this type, with the track carried on ballast.

(b) *Metal spraying.* — This method consists in projecting a metallic film obtained by pulverising metal melted in the flame of a portable gun over the surface to be protected.

One such method, the Schoop process, in which the protecting metal is obtained by melting a wire, was tested on the French State Rys. in August 1923, in order to protect part of a girder in the parcels office of the St. Lazare Station.

One year later, most of the protecting coat had come away from the metal.

2. Smoke screens.

Some Railways provide smoke screens under their structures, consisting of cement sheets, or tiles, or special bricks (the Pont de l'Europe, in Paris, with Poyet bricks under the raft encasing the lower members of the main girders — fig. 11, is an example).

These screens which should have a smooth

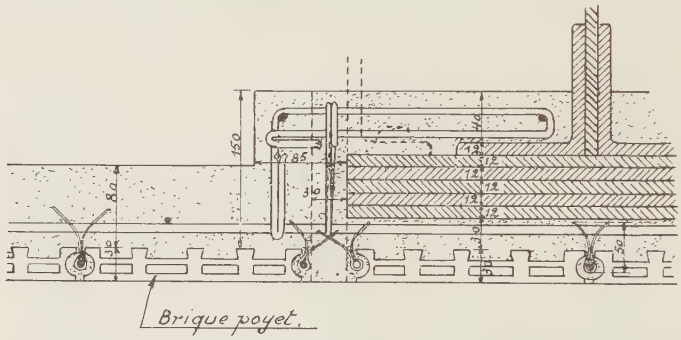


Fig. 11. Pont de l'Europe, in Paris. — Protection by Poyet bricks.

surface so that the smoke can get away more quickly than it would from cells in which it could eddy, are relatively difficult to fit because as a rule they have to be fastened up in such a way that they can easily be removed to inspect the lower part of the structure, unless there is room to examine it from above; one arrangement for fastening the slabs consists of an angle and plate support secured to the lower members of the bridge (fig. 12).

Figure 13 shows an arrangement of a

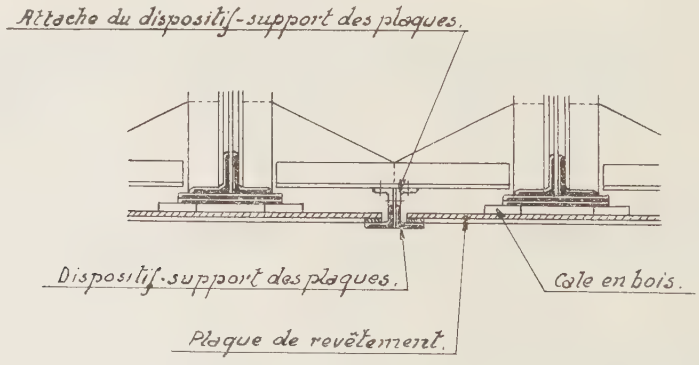


Fig. 12.

Note. — Attache.... = Fastening of device supporting the slabs. — Plaque de revêtement = facing slab. — Cale en bois = wooden distance piece.

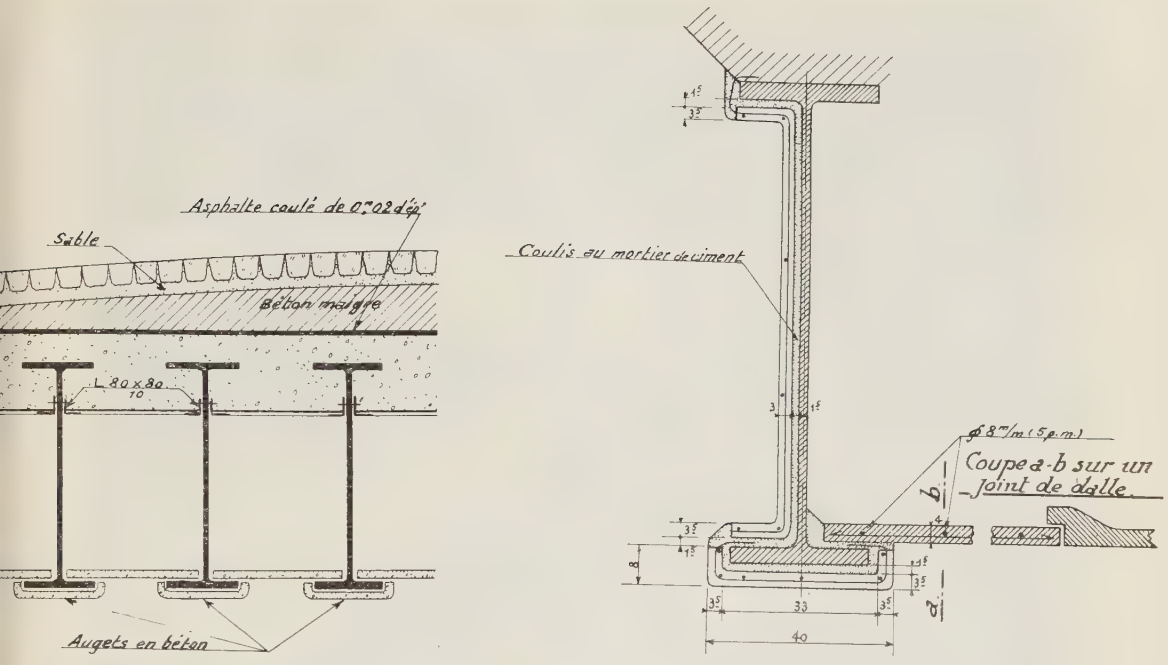


Fig. 13.

Note. — Asphalte.... = 2 cm. layer of asphalt poured on. — Sable = sand. — Béton maigre = poor concrete. — Augets en béton = concrete troughs. — Coulis.... = Cement grouting. — Coupe.... = Section a-b on slab joint.

precast reinforced concrete smoke screen used on an over-bridge with 1 000 m. (3′ 3 3/8″) deep encased girders.

The maintenance of bridge expansion devices and especially their cleaning and greasing is of the greatest importance. Several railways report that this is done periodically.

It is frequently found that the bearing blocks and underlying masonry require heavy repairs. This is the usual consequence of badly designed buttresses. The question is the more important as these are vital parts of the structure. Specially interesting equipment is in use on the *Nord Ry.* for carrying out these repairs, consisting of 150-ton jacks distant-operated by pumps. These jacks can be coupled together ; figure 14 shows them in action.

General remarks.

In view of the general increase in the running loads and speeds, the problem of the inspection and periodical maintenance of metal bridges — especially under-bridges — is of growing importance. As a rule this work is in the hands of special staff under the Permanent Way Department. They usually prefer to do the work themselves, particularly the painting which is more likely to be done properly, especially as regards cleaning and removing all traces of rust from the structure. In addition it is much easier to limit the work done to that strictly necessary.

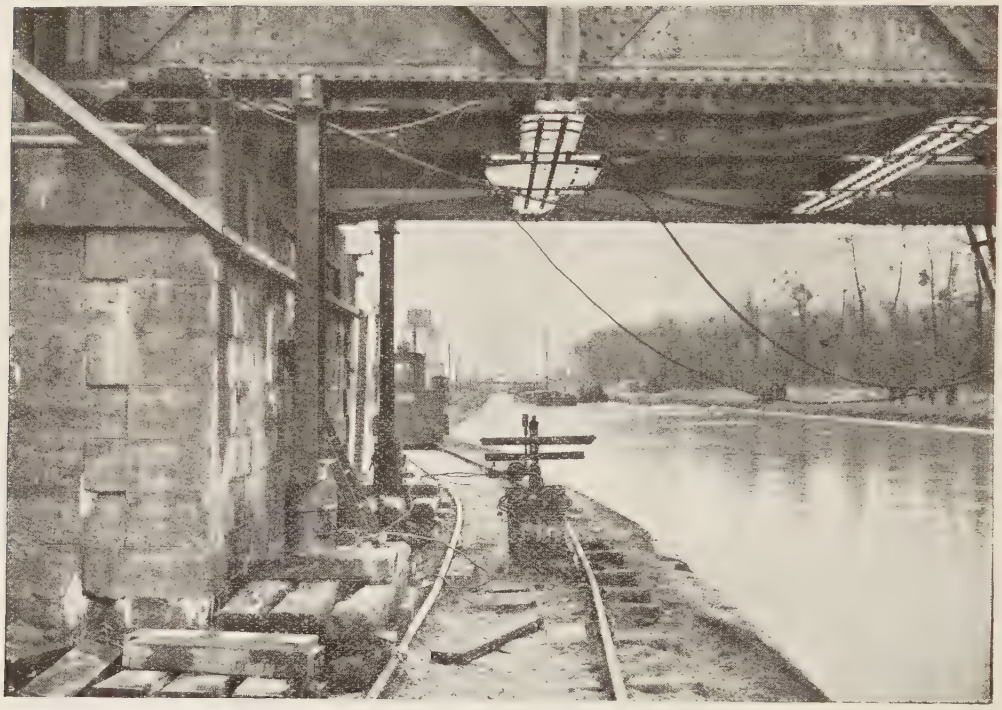


Fig. 14. — 150-ton coupled jacks.

Mechanical methods for cleaning and repainting are not generally used. Only a few Railways report their use as an experiment.

The paints used generally consist of a pigment (red lead or iron oxide, white lead, zinc white, graphite, micaceous iron, powdered aluminium) and boiled linseed oil with the addition of a little drier.

Electric welding is frequently found to be a simple and economical method of repairing and strengthening bridges.

As painting is found inadequate in many cases to protect the lower parts of metal over-bridges, special methods of protection (casing and smoke plates) are frequently used.

Rustless steels (e. g. copper bearing steel) in view of their resistance to corrosion may reduce the cost of maintenance of these parts.

Certain parts of metal structures which are not properly ventilated (especially the ends of bridges) are subject to much greater corrosion owing to the permanent humidity and the difficulty of getting at them and maintaining them. They must, therefore, be given particular care at the time of periodical maintenance. It is also desirable to improve the design of the buttresses by opening up the ends and doing away with any contact between the steel work and the ballast or ground.

* * *

2. — Methodical and periodical maintenance of signals.

The following railways were good enough to supply information : The

Bulgarian, Egyptian, Hellenic, French, Italian, Rumanian, Czechoslovak and *Jugoslav State* Railways. the *Alsace-Lorraine, Est, Nord, P.O.-Midi, P.L.M., Portuguese, Algerian, Damas-Hamah, French Indo-China* Railway Companies, and the *Government General of French West Africa.*

Organisation.

The maintenance of signals is organised in widely different ways on the railways with which the present report deals.

A special service responsible for maintaining the mechanical and electrical signal equipment is the most usual. This service is usually responsible to the Permanent Way Department. In Czechoslovakia, however, its attachement to the Operating Department is under consideration. In Italy it is a branch of the electrified lines service.

The signal service on the *Rumanian Rys.* is organised as a separate department with sections in each division. The headquarters department is divided into technical offices dealing with :

(a) Mechanical and electro-mechanical equipment for point and signal operation;

(b) Electro-dynamic equipment for operating the points and signals from central power boxes, and also the block signals;

(c) Telegraph, wireless;

(d) Telephone, traffic control;

(e) Electric light equipment, electric clocks;

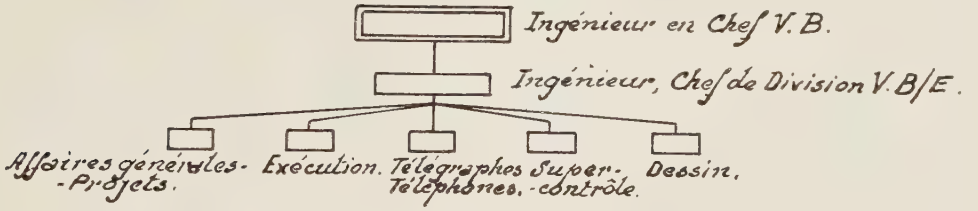
(f) Lift bridges, telegraph, shops;

(g) Control of consumption of electricity.

The outdoor service consists of sections, ten in number. Each section has a length of lines varying from 880 to 1 785 km. (546 to 1110 miles). The staff of a section consists of an engineer, one or two assistant engineers, and inspectors.

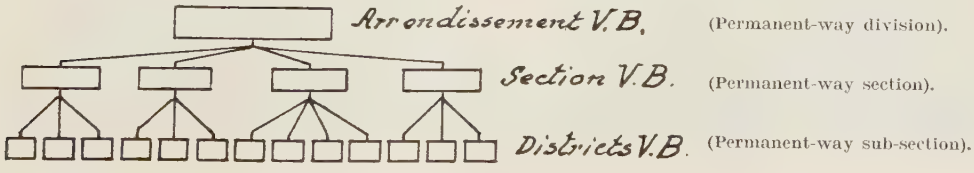
On the *Czechoslovak State Rys.* the signal service is undermanaged by a special office of the Ministry of Railways. In each of the seven divisions there is a special office and a signal shop.

On the *Alsace-Lorraine Rys.* there is a special service with a central organisation, according to the diagram hereafter



Note. — Ingénieur en chef.... = chief engineer. permanent way and buildings. — Ingénieur, chef.... = divisional engineer, permanent way and buildings. — Affaires générales = General matters. — Projets = schemes. — Dessin = drawing office,

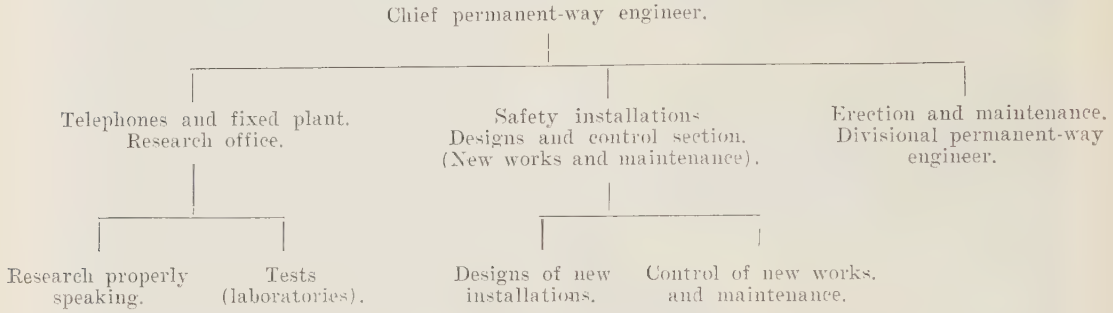
and a regional organisation according to the diagram :



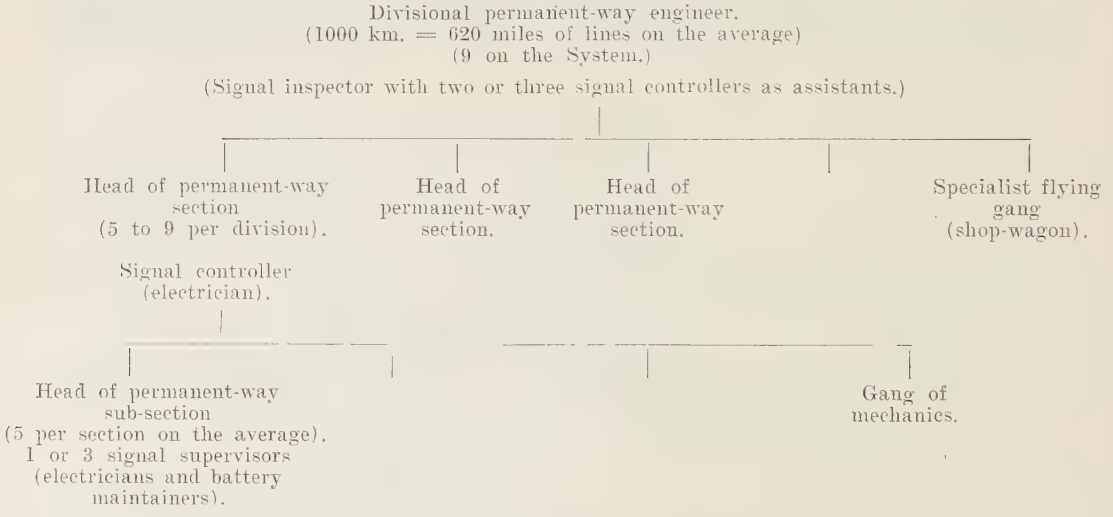
with an inspector responsible for maintaining the signals per division.

P.L.M. Ry. Co. — Maintenance of mechanical signalling carried out by permanent-way maintenance staff. The electric signalling comes under a special organisation under the permanent-way department, (central and area organisation), with an inspector of the electrical department in each of the 11 divisions.

French State Rys. — A designing service at headquarters according to the diagram :


Chief permanent-way engineer.
Telephones and fixed plant. Research office.
Safety installations Designs and control section. (New works and maintenance).
Erection and maintenance. Divisional permanent-way engineer.
Research properly speaking.
Tests (laboratories).
Designs of new installations.
Control of new works and maintenance.

and the divisional engineers of the permanent way department control new work and look after the maintenance (under the permanent control of headquarters) according to the following diagram :


Divisional permanent-way engineer.
(1000 km. = 620 miles of lines on the average)
(9 on the System.)
(Signal inspector with two or three signal controllers as assistants.)
Head of permanent-way section (5 to 9 per division).
Head of permanent-way section.
Head of permanent-way section.
Specialist flying gang (shop-wagon).
Signal controller (electrician).
Head of permanent-way sub-section (5 per section on the average). 1 or 3 signal supervisors (electricians and battery maintainers).
Gang of mechanics.

The organisation on the *French Nord* is like that of the *French State Rys.*

Algerian Rys. — Mechanical part maintained by the permanent-way maintenance department, and the electrical part by the electrical section under the operating department.

Method of operation.

We have summed up in Table II, from

the replies received to the questionnaire, the number of levers operated : *(a)* mechanically, *(b)* electrically, and *(c)* by other methods : (hydraulically, electro-pneumatically, etc.) on the different Railways.

TABLE II.

	Number of levers operated :		
	Mechanically. (*a*)	Electrically. (*b*)	Other means. (*c*)
Bulgarian State Rys.	628	480	...
Egyptian State Rys.	9 780	117	...
Italian State Rys.	10 167	6 530	14 043
Rumanian State Rys.	4 600	142	...
Czechoslovak State Rys.	24 760	131	108
Jugoslav State Rys.	7 274	...	...
Alsace-Lorraine Rys.	14 300	1 200	...
Est Rys.	9 240	1 120	...
French State Rys.	13 460	1 628	348
P.L.M. Rys.	16 945	1 462	60
Nord Ry.	23 000	3 700	1 200
P.O.-Midi Rys.	22 800	2 100	300

Staff.

The average number of men under each divisional inspector varies. For information the figures for some of the railways are given below :

Italian State Rys. — 14 divisions, 4 inspectors per division (600 levers per inspector) with, for each inspector, 1 or 2 technicians, 5 assistant technicians or first-class workmen, and 100 workmen or labourers.

Est Rys. — One division has 1 320 mechanical levers and 160 electric levers. Staff : 1 inspector, 2 assistant inspectors, 8 controllers; gangs of men belonging to the electric department with 40 supervisors, 45 assistant supervisors, and 40 platelayers, as well as signal and interlocking gangs with 4 leading workmen, 12 assistant leading workmen, 40 ordinary workmen, and 22 platelayers.

French State Rys. — 1 inspector per division with, on the average, 1 500 levers, and 1 controller for the electric service per section (see diagram), and 170 mechanics and electricians per division.

Nord Ry. — Per division : 3 285 mechanical levers and 530 electric levers. One inspector with an assistant per division, 150 men (workmen and assistants) supervised by some 20 controllers.

Working hours.

The usual number of hours per day is eight, and 48 hours per week, this usually including travelling time. Certain exceptions are, however, reported. 50 % of the journey time is taken into account on the *Est* and the total number of hours per day must not exceed 13 hours. On the *Nord* the rules lay down the equivalent in actual working time, of time spent in trains, stations, or

walking. In the case of special work or incidents, the number of hours per day must not exceed 10 (24 hours in case of accidents) with compensation in time off duty within 90 days at most.

On the *Italian Rys.*, the 8 working hours do not include travelling time, and the maximum number of hours that can be worked per week is 56, with compensation.

In Czechoslovakia, the day is 8 hours, but the signal staff, in the interests of safety, has to be available for work at all times. Special allowances are made to them.

Work by gangs at very busy centres is in force on some Railways *(Italy, Est, Alsace-Lorraine, Egyptian State).*

On the *P.O.-Midi,* the night shift has only supervisory duties to perform; maintenance gangs work 8 hours, and supervisory gangs whose service is broken, 12 hours.

The inspector is usually responsible for the various systems of signalling, although a special staff is frequently used for maintaining the electric signalling equipment.

Professional training.

In Rumania specialised staff have to attend courses in a special school for 2 years.

The *French State* has, for the railway as a whole, a school through which all the electricians and mechanics have to pass, the normal course being 3 months. There is also a practical school in each division; the instruction therein is given on certain days only.

As a rule the men are recruited by examination amongst those on probation in the maintenance gangs. A selection is made when engaging staff to become specialists, and their professional instruction is received from their immediate superiors during work.

Promotion as a rule is by seniority and merit.

Rules and regulations.

None of the railways report any printed rules and regulations to guide the inspectors or controllers, giving details of the duties they have to fulfil. Certain companies have such regulations under consideration.

The headquarters — or divisional service — is generally kept informed as to movements of the inspectors by means of reports sent in.

The condition of the equipment is usually reported on by the inspectors. On the *French Nord,* the inspector or one of his assistants have to inspect each signalling equipment twice a year in the presence of the heads of the section or of the sub-section.

This inspection is reported in detail, one copy of the report being sent to the chief engineer for maintenance. This report is the basis on which the whole programme of the repair work on the installation is based.

On the *Italian State Rys.* a quarterly report is made on the condition of the equipment. In addition, yearly or half-yearly inspections, according to the size of the installations, are carried out in the presence of delegates of the operating department.

The inspectors and controllers during their rounds of inspection as a rule test the mechanics and electricians to see they are thoroughly familiar with the rules. In Italy they are examined periodically.

The station staff usually keeps a register of the addesses of the maintenance staff. On some French railways and in Italy, these lists have to be displayed in the signal boxes.

Disconnection of levers. Inspecting and testing the interlockings.

The operating department usually gives a written authority for any work required in connection with the safety appliances. Written instructions lay

down the safety measures to be taken by the signalmen and by the repair gangs during the whole period of the work. In addition a frequent practice is to put a written notice on the levers and lock them in position mechanically.

Most of the companies issue a programme to the maintenance staff (mechanical and electrical) so as to ensure each equipment being inspected regularly. The frequency of these examinations, however, varies considerably, as does that between cleaning and oiling the mechanical interlockings.

The frequency of repairs to mechanical parts is very variable.

The organisation on the *French State Rys.* should be noticed :

(1) *Inspection of the mechanical and electrical installations :*

Inspection of the equipment as regards working and good general order : made quarterly by the head of sub-section and the stationmaster ; made annually by the head of the section and the operating department inspector.

Technical inspection, general and detailed, made annually by the divisional signal inspector or controllers.

(2) *Maintenance :*

Repairs carried out according to the equipment and the way it is used (heavy repairs : 1 to 4 years — light repairs yearly).

As a rule the ordinary repair staff is not authorised to remove a mechanical lock in order to clean or oil it.

Alterations in the mechanical interlockings are usually carried out by trained men on the maintenance side (or by contractors on some *French Rys.).* These alterations are agreed by headquarters.

The periodical testing of the interlockings by the signalmen is not generally provided for, but they have to report all defects observed. Such tests as a rule are made by the supervisory staff. The following is a reproduction of a report of one of the quarterly examinations in force on the *Est Ry.* (Appendix A).

Spare parts.

The maintenance staff is allowed to hold a small stock of spares based on the monthly to quarterly consumption. This stock is frequently kept in the sub-section stores or in the case of certain large equipments in the signal box.

In this case they are charged against the head of the sub-section and the maintainer is given space to store them in the signal box.

The maintenance men and inspectors are held responsible for the proper lighting of the signal lamps. A fixed inspection period is not laid down as a rule; the period between inspections is shorter in winter.

The maintenance men properly speaking as a rule work alone, whereas men carrying out the periodic overhauls always work in gangs. Printed instructions for these men are available on certain French Railways. The instructions in force on the *French Nord* are reproduced in Appendix B.

Detector slide clearance.

The clearance allowed in the case of slides or lock gear is very variable (2 to 5 mm. = 5/64″ to 3/16″).

Some companies use a standard gauge by which the electric point control gear can be checked. On the *French State* this control prevents the signals being taken off if the switch is more than 5 mm. (3/16″) off the stock rail, and if the locks have not travelled more than half their stroke.

Where signal wires cross the track, they are taken through the space between two sleepers from which the ballast has been removed or are protected by wood, masonry, or concrete trunking (precast sections in the case

APPENDIX A.

EST RAILWAYS

Way and Works

REPORT

on cross-inspection of apparatus and signals of a Post

(Art. 9 of General Order No. 9).

STATION or YARD : .....

Post : .....

Inspection of ..... **quarter, 19** ..

All apparatus and signals work well, with the exception of the following :

EST. — FORM. 1138

APPARATUS.	WORKING CONDITION, KIND OF DEFECTS FOUND, LACK OF MAINTENANCE FOUND, ETC.

Date

Signature . . . . . (STATION MASTER [OR HEAD OF SERVICE]).

Signature . . . . . (HEAD OF SUB-SECTION.)

Signature . . . . . (SUPERVISOR OF ELECTRIC SERVICE.)

After examination, passed on to :

The Head of the Regional Operating Service,

The divisional Permanent-Way Engineer.

Signed . . . . . (INSPECTOR.)

Signed . . . . . (HEAD OF SECTION.)

APPENDIX B. *(Recto.)*

Division No. .....
Section No. .....
Sub-Section No. .....

STATION : _____ NORD RAILWAY.

*To Mr.*_____*Head of Sub-section.*

Programme of _____
Phase No. _____
Operation No._____

WORK ORDER.

Nature of work to be carried out.	
Effect on the working of the installations (Immobilisation or disconnection of apparatus, interlockings temporarily eliminated, etc.)	

Date carried out : from _____ **at**_____**(h** ____**m.)**

to _____**at**_____**(h.**____**m.)**

Noted. Work to be carried out by :

*Mr.*_____ Signature . . . . . ,
(Head of sub-section)

TO BE SIGNED BY THE HEAD OF THE SUB-SECTION AND BE HANDED TO THE WORKMAN AFTER COPY NO. 4, SIGNED BY THE STATION MASTER, HAS BEEN RECEIVED.

(See important recommendations on back page).

APPENDIX B. *(Back.)*

Important recommendations.

Before starting work. — On receipt of the present order you shall have to read it through carefully, so as to be fully alive to what is required from you when carrying out the work.

If you are not sure you have understood well all the terms, you shall request further explanations from the head of your sub-section.

You should realize all the consequences of the work which is the object of the present order, on the working of the apparatus, on train operation and on the station working, and if *all* these consequences are not mentioned in the order, you should advise the head of the sub-section immediately, so that he should examine the question, and if necessary, complete the indications given.

Further, should you not believe it possible for you to carry out the totality of the work stated in this order in the time allotted, you should also inform the head of your sub-section, so that he may have the period lengthened, or give you explanations or assistance with a view to observing the time limit originally laid down.

Starting work. — It is only after having read and understood the present order in all its details and having:

1. Realized the possibility of strictly adhering to its prescriptions;
2. Made sure that the official of the operating department has been advised of this work and that he has caused all the prescribed safety measures to be taken;

that you shall be able to undertake the work indicated, and that only, on the date and time stated.

When the work is being carried out. — Unforeseen necessities of the operating service may cause the work to be stopped temporarily, and demand that either part or the whole of the preexisting situation be restored, or the immediate putting into service of such provisional arrangements as may be demanded by circumstances. In such a case you should conform without any delay to the orders given by the *head of the sub-section* or his representative, or exceptionally in his absence, by the *station-master*.

In the latter case, you should request a written order from the station-master and forward it to the head of the sub-section by the quickest means available, in order to keep him acquainted with the situation.

In any case, you should only resume the work when ordered to do so by the head of the sub-section.

If, owing to quite unforeseen circumstances, after you thought it possible to complete the work within the time alloted, you find later on you will be unable to do so within the limit laid down, you must, as soon as you realise this impossibility to finish in due time, advise the head of the sub-section and the station-master, in order to enable them to agree on the necessary steps to be taken.

It may be necessary, whilst carrying out the work, to move levers actuating certain apparatus; in such a case you have to request the signalman usually in charge of same to move these levers himself, or allow you to move them in his place, after he has received permission from the station-master, to let you do it but in his (the signalman's) presence, under his direction and his responsibility

You are absolutely forbidden ever to move a lever outside the presence of the signalman usually in charge of same, and further if this employee has not given you, for each lever operation, permission to do so.

The same prescriptions regarding the operation of levers are also applicable to the operation, by any means whatsoever, of the apparatus themselves, whether provided or not with levers, and to the operation of the keys of Bouré locks of any type.

Should you have to be relieved by another fitter (or assistant-foreman) in the course of your work, you should hand him the present order before departing.

After completion of the work. — When the work stated on the present order has been carried out, *you must not leave the site of same until the head of the sub-section or his delegate, or in their absence the station-master, have verified the good functioning of the newly connected apparatus or which are put into service again after a momentary interruption.*

Important notice (to be struck out if the execution order has not been handed to an assistant foreman). — You have not only to personally conform to all prescriptions of the present order, but also to watch with the greatest care that they be observed by all workmen cooperating, under your orders, to the carrying out of the work therein specified.

Signature : . . . . . .

(Head of the Sub-section.)

of concrete), or in cast iron, steel or concrete pipes.

Tool equipment.

The tool equipment available for the men is very much the same on all railways. The usual practice is to keep an inventory of the tools issued to the men.

Types of signals.

On the French Rys. the mechanically-operated semaphore signals are arranged to show line clear in the lower quadrant (the angle with the vertical varying from 0 to 15°). The *Alsace-Lorraine* is an excepion, *line clear* being indicated by an arm at 45° in the upper quadrant. This is also the practice in Czechoslovakia, Jugoslavia and Rumania.

In *Italy* the lower quadrant with an angle of 36° to the vertical is used.

On the *Portuguese Rys.*, three-position signals are used in the upper quadrant (45° *caution*, 90° *line clear)*. As a rule the signal posts are fitted with steps or ladders. Platforms with handrails for the lampmen are not usually provided except in the case of brackets or gantries with many lights.

The signal poles are frequently fitted with lamp winches worked from the ground by means of a chain; the maintenance men are provided with safety belts for use when working on the signal posts.

The maximum distance, from the boxes, of mechanically operated signals is 1 000 to 2 000 m. (3 280′ to 6 560′). The *French Rys.* frequently extend it to 2 500 m. (8 200′).

Tests and inspections, either yearly or twice yearly, are carried out on most railways by the heads of the section or sub-section, or controllers, for checking the electric locking and the electric interlocking circuits.

Electric signal lamps.

Some railways record the number of hours the lamps burn. On the *Est* the lamps are changed after 66 % of the life ascertained in the laboratory under 10 % over-voltage. On the *P.O.-Midi* the red light lamps are changed after 80 % of their nominal life.

The *Italian State Rys.* replace the lamps on lines equipped with the automatic block after they have burnt 80 % of their nominal life.

Point rodding.

Point rodding of tubing is the most frequently used. The sizes are : 0.027 to 0.033 m. (1 1/6″ to 1 5/16″) inside and 0.034 to 0.042 m. (1 3/8″ to 1 21/32″) on the outside.

They are repainted periodically as necessary (3 to 5 years).

The *Egyptian Rys.* paint the rodding annually.

Red lead is usually employed with one or more coats of light colour, though sometimes anti-rust paint it used.

Signal arms.

Wood arms are going out of use. Most railways are using enamelled metal arms. Before painting they are scraped and washed (soda and soap). The use of enamelled arms is becoming general.

When the signals or signal lights are repeated in the locomotive cab, the circuit is generally closed, the source of energy being at the signal.

Track circuits.

Some companies keep a statement of the track circuit inspections. For example on the *P.L.M.*, a record book exists, for each maintenance length, in which the results of the monthly inspections are entered. The results are controlled by tests carried out by the controllers when going over the line. On the *Nord* such records are only kept in the case of main-line automatic block light signals. The tests are carried out every month by the maintainer and every

six months by the inspector. The records are sent to the laboratory where an index is kept of the circuits and their adjustment is watched.

Minimum shunt value allowed for the train.

The track relay should operate when the resistance of the track circuit is 0.15 ohm in the case of the *Alsace-Lorraine Rys.*

On the *Est* insulated sections are so arranged that a shunt of 0.06 ohm set up by the train between the rails operates the equipment. This resistance will be increased to 0.15 ohm at least.

The *P.L.M.* adjust the small insulated sections for a shunt of 0.3 ohm and also the automatic block track circuits; the other circuits are adjusted for a shunt of 0.14 ohm. These values are always maintained as they have been calculated on the most unfavourable conditions occurring in practice.

The maximum length of the circuits varies much : from 1 500 to 2 000 m. (4 920′ to 6 560″).

On the *P.L.M.* with ordinary ballast, (2 ohms insulation per km.) the length of the direct-current track circuits does not exceed 1 500 m. (4 920′). In tunnels where the insulation can fall to 0.15 ohm per km. the length does not exceed 500 m. (1 640′).

When the condition of the ballast does not allow of the proper shunt being maintained, the track circuit is divided up.

Types of insulated joints.

The Weber joint with a saddle and two wood fish-plates and four electrically insulated bolts is the one most commonly used.

After having tried various types of insulated joints, the *Nord* now uses joints with *two* steel fish-plates with vulcanised fibre joints between.

The insulated joints are maintained as a rule by the permanent way staff (under the control of the electricians).

On the *Alsace-Lorraine, Rumanian State, Italian State, Jugoslav State,* and *Portuguese Rys.* the signal staff are responsible for this work.

The track-circuit relays are inspected at various periods. On the *P.L.M.* they are checked in position every year, and are thoroughly overhauled every five years.

Electric locks.

The arrangements for fixing the electric locks vary according to the type of interlocking frame and locks. In most cases the locks are above the floor and in front of the frame.

Circuit makers.

On the *P.O.-Midi* the control circuit is open when the dial has moved 22° from the closed position, which alone is controlled.

On the F*rench State,* the opening is only controlled for an angle of 10° from the fully open position. The closed position is only checked 10° from the fully closed position.

On the *Alsace-Lorraine,* the danger indication repeaters change colour when the signal arm is at 10° or after 30 mm. (1 3/16″) travel of the operating rod. The line clear indication repeaters change colour when the arm is at 30° or after the operating rod has moved 100 mm. (3 15/16″) (line clear position 45°).

In *Italy* this proportion is 5° as when going from *stop* to *line clear,* and 15° for the reverse operation.

In Czechoslovakia, this proportion is about 1/5th of the rotation or 9°.

Periodical overhaul and cleaning of point motors.

The periodical overhaul and cleaning of motor-operated point machines is generally done by arrangement with the operating department. Normal traffic is not as a rule interfered with. On the *French Nord,* speed restrictions are imposed by keeping the *caution* signals *on* when the interlocking between levers

has been cut out. Ordinary inspection (lubrication, cleaning contacts, etc.) is done in agreement with the signalmen.

The necessary connections are removed from the distribution boxes to prevent the switches being worked. The maintenance staff arrange with the signalmen to operate the points if necessary for them to do their work properly.

Automatically-charged accumulators.

Generally the charging rate is regulated in such a way as to avoid overcharging. On the *Est Ry.* the charging current is cut off once a month (monthly discharge).

Materials used.

Mild steel is being used more and more extensively for building signalling equipment.

The *Czechoslovak Rys.* allow the rodding to be electrically welded and are satisfied with the results obtained.

Signal poles are usually of the trellis work or tubular type (especially in *Czechoslovakia* where the tubular post is used exclusively). The *Bulgarian State Rys.* are using reinforced concrete signal posts.

Metal signal poles are repainted at varying intervals; the average being about two years. The type of paint is that usually employed on structures (red lead, zinc white, anti-rust paint). The *Czechoslovak Rys.* sent us the specifications in use on their system for oil paints and enamels used for the signals and other safety apparatus. Certain details taken from these specifications are given below (Appendix C).

APPENDIX C.

Specification for paint.

The paint should be supplied ready for use. It should dry within 24 hours at a temperature of 18 to 20° C. (64 to 68° F.). In preparing the paint, oil driers only are to be used, without the addition of resin or any compositions of resin. The material supplied should be constant as regards the effect of light and weather, and the colour should neither fade nor become darker.

As regards shades, the oil and varnish paints should meet the standard types of the Czechoslovak specifications No. 1017-1927 « Paint and varnish shades for general purposes » :

Red shade : cinnabar (red mercuric sulphide);

Green shade : grass green;

Blue shade : blue No. 6 (ultramarine);

Grey shade : mouse grey No. 4.

Black shade : black No. 18.

The pigment must be ground very fine, with no granulated particles, and should not contain — unless authorised — kaolin, baryta white, barytine, baryta, gypsum, chalk and other additions.

The zinc white must contain at least 99 % of ZnO. Lead white must be pure. Bone black should be a very deep black and not contain any elements soluble in water nor any uncarbonised organic materials. It should be very finely ground.

For thinning down, turpentine, refined resin oil, distillates of naphta and hydronapthalene may be used. The solvents should be clear and colourless, and without any disagreeable smell.

Oil paints should flow freely from the brush and be applied easily, covering the surface properly whatever the thickness of the coat.

The dry surface should be shiny, uniform and elastic.

The *varnish paints* should flow freely from the brush, and lay well; they should blend well, and it should be possible to brush over several times without leaving brush marks.

They should resist the action of a soda solution and a moist atmosphere saturated with sulphur dioxide.

Resistance to a 5 % soda solution at 50° C. (122° F.).

After being applied on a steel plate perfectly free from rust (the cleaning is done by sand blasting or by metal brushes, then with emery paper) the paint, after drying 48 hours, should stand being soaked for one hour in the above mentioned solution of soda at 50° C. (122° F.) and a violent jet of water for a minute, without any part of the coat coming away. When the water has dried off the paint should remain bright.

Resistance to a moist atmosphere saturated with sulphur dioxide.

After drying 48 hours, the coat after being exposed for 24 hours to the atmosphere in question should not change colour nor become very sticky.

The coat when dry should be elastic, i.e. there should be no cracks nor defects after bending and straightening.

Composition.

A. *Non-rusting base coat.*

Colour.	Linseed oil, maximum contents, %.	Solvent (liquid components). Maximum contents, %.	Pigment. Quantity = 100 — (colour plus solvent).
		A. — *Anti-rust ground coat.*	
Red.	15	...	Pure red lead.
		B. — *Oil paints.*	
White.	20	15	Zinc white.
Black.	25	20	Bone black.
Red.	20	10	Organic colouring matter unaffected by light.
Green.	20	10	Chrome yellow and Paris blue.
Blue.	25	15	Ultramarine.
Grey.	20	15	White lead and bone black.
Green.	20	10	Chrome yellow, Paris blue and bone black.

C. — *Varnish paints.*

Colour.	Binding matter. minimum contents, %.	Solvent (liquid components). Maximum contents, %.	Pigment. Quantity = 100 minus (binding matter plus solvent).
White.	50	25	Zinc white.
Black.	50	25	Bone black.
Red.	50	25	Organic colouring matter, unaffected by light.
Green.	50	25	Chrome yellow and Paris blue.
Blue.	50	25	Ultramarine.
Grey.	50	25	Zinc white and bone black.

Colloidal oil, very adhesive and with a very low freezing point, (— 36° C = — 32° F.), and not removed by water is generally employed for lubricating equipment out of doors. For lubricating motor mechanisms, points, and signals, very pure and fluid oils are used, whereas recovered oils are used on slide chairs as a rule.

Some railways report the use of graphite for lubricating the interlocking tables; the graphite mixed with a little paraffin is brushed on.

The lamps used in colour-light signals are replaced after 1000 lighting hours on the *Alsace-Lorraine* and *Est Rys.* This period is increased to 1 500 hours on the *P.L.M.* and *French State,* and to 2 000 hours on the *P.O.-Midi.*

As a rule the lamps are generally underrun by 5 to 10 %. The period after which the lenses, glasses, and lamps of colour-light signals are cleaned varies with the particular conditions.

Steps taken to guard against phantom indications due to reflected external light sources.

As a rule the back of the lamp case is painted dull black and hoods are fitted. On the *French Nord,* very long hoods are fitted in front of the lamps and an inclined transparent glass is fitted in front of the lens of the lamp, intended to reflect towards the inside of the hood any light rays coming from the outside.

The *Italian State Rys.* use signals with one lamp with moveable coloured light screen (roundels).

As a rule the maintenance staff are obliged to close the door or covers should a train approch so as to prevent false indications being given during maintenance work.

When lamp relays are used with double-filament lamps, the relay is adjusted to drop when the main filament is used up. The *P.L.M.* alone does not follow this rule, but the relay drops when the two filaments are burnt out.

Cab signals.

The *Italian State* and *P.O. Rys.* have sent some information. The *P.O.* uses audible repetition and records the distant signals or speed restriction signals passed in the *on* position.

The permanent-way electrical section looks after the permanent-way equipment and the locomotive running department (shed) maintains the equipment on the locomotives.

The equipment on the locomotive is tested on leaving the shed on a trial ramp, whereas the permanent-way equipment is systematically inspected every three months by a special train. The maintenance is done by the electricians of the section.

The *Italian State Rys.* have adopted the Minucciani automatic train control system. The electrical engineer of the section is responsible for maintaining the permanent-way equipment, and the equipment on the locomotives is tested on leaving the shed. Every year the magnetisation of the magnets is tested. This Administration issues special instructions on the maintenance of automatic train control gear.

* * *

3. — Methodical and periodical maintenance of the metal supports carrying the contact lines on electric railways.

The following five Administrations operating electric lines have replied to the questionnaire in this respect :

1. Italian State Rys.;
2. P. O.-Midi Rys.;
3. P. L. M. Rys.;
4. French State Rys.;
5. Algerian Rys.

Table III gives the total length of the electrified lines and the normal spacing of the supports on the straight for each of these Railways.

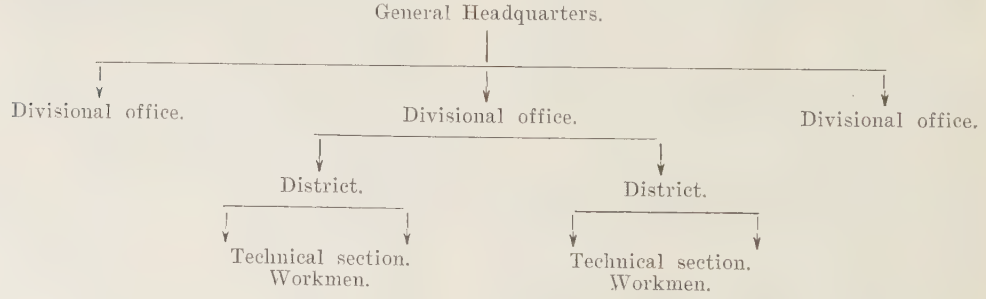
TABLE III.

Railways.	Total length of electrified lines, km.	Total length of lines equipped with overhead contact lines, km.	Spacing of supports.
Italian State Rys.	*a)* 3-phase, 3 700-V., 16 2/3 cycles . 1 600 *b)* 3-phase, 10 000-V., 45 cycles . . 120 *c)* D.C., 3 000-V . . . . . 1 257 *d)* D.C., 750-V. . . . . 73 Total : 3 110		*a)* 3-phase installations : 1. With longitudinal suspension : 50 m. 2. With transverse suspension : 35 m. *b)* D.C. installations : 60 m.
P.O.-Midi Rys.	Running roads : 1 545 Sidings, etc. : 609.	650	63
P.L.M. Rys.	Running roads : 308 Sidings, etc. : 84	37 84	63 25
French State Rys.	Running roads : 207	(under construction) 810	63
Algerian Rys.	163	163	60

The 207 km. (128.6 miles) of the French State are equipped with third or conductor rails. The overhead equipment (on 810 km. = 503 miles) now being erected, this Railway is unable to reply to all parts of the questionnaire, especially as regards maintenance.

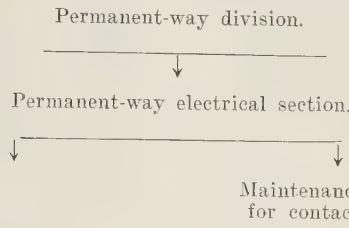
Organisation.

Italian State. — Special staff for the supports of contact lines and for maintaining the overhead equipment organised according to the following diagram :

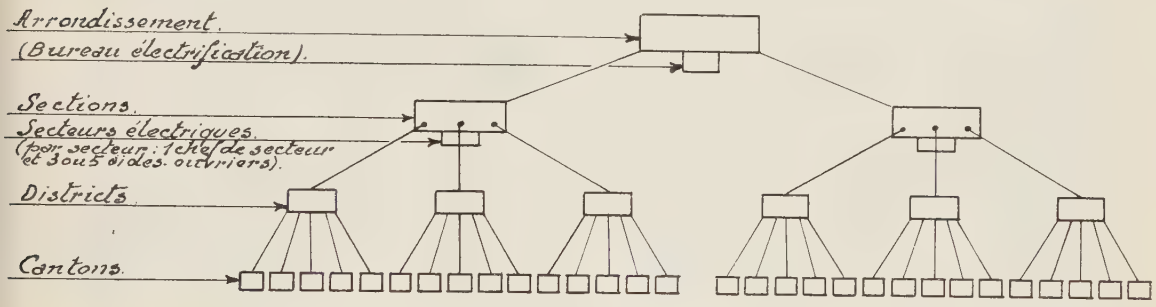


P.O.-Midi Rys. — The gangs for maintaining the overhead lines form part of the electrical section of the permanent way department and are responsible for maintaining and inspecting the whole of the overhead equipment including the supports.

Organisation diagram.



On the *P.L.M.* the organisation is also part of the permanent-way department as shown in the following diagram :



Note. — Arrondissement = division. — Bureau électrification = electrification office. — Secteurs électriques (par secteur . . . .) = Electrical sectors (per sector : 1 linesman and 3 to 5 helpers). — Districts = sub-sections. — Canton = length of track maintained by one gang.

Electric traction equipment : 3rd rail, overhead contact lines, high-tension lines are inspected and maintained by the ordinary staff of the service (sections and sub-sections) with the help of specially trained staff in the electrical sectors which belong to the sections.

The *French State* is considering the maintenance of the supports by special gangs attached to the permanent-way department.

Algerian Rys. — The maintenance is carried out by the mechanical engineer's department, according to the following organisation : there is a gang of six men in each substation, who maintain the supports and the contact line and work the substation (six men per 41 km. = 25.5 miles). This staff comes under the divisional mechanical engineer and has over it an inspector assisted by two controllers.

Staff.

Number of men per kilometre :

The following average figures have been given on the staff per unit length of track fitted with overhead contact line.

Italy : 0.30 to 0.40 man per km. (0.5 to 0.64 man per mile) of track.

Algerian Rys. : 0.14 man per km. (0.224 man per mile).

Inspection of supports.

On the *P.L.M.* weekly inspection by men in the electrical sectors and quarterly visit by the heads of sections. On the *P.O.-Midi* the supports are examined

by the staff maintaining the contact lines (under the permanent-way electrical service) at the same time as the rest of the equipment.

In *Italy* the inspection takes place every month.

Types of support.

Tubular supports are used as a rule on the *Italian Rys.* Figure 15 shows the way the 3 000-V.D.C. contact lines are supported longitudinally. Figure 16 shows the transverse suspension gear for 3-phase 3 700-V. 16 2/3-cycle current.

The *P.O.-Midi Rys.* use on the running roads assembled U posts and I posts with large flanges (Grey type). On secondary tracks the Grey type joist is used exclusively.

On the *P.L.M.* lattice supports made of steel having a breaking strength of 54 kgr./mm² (34.3 Engl. t. per sq. in.), with 20 % elongation, are used. Figure 17 shows the design of a support used by this Railway on the running roads.

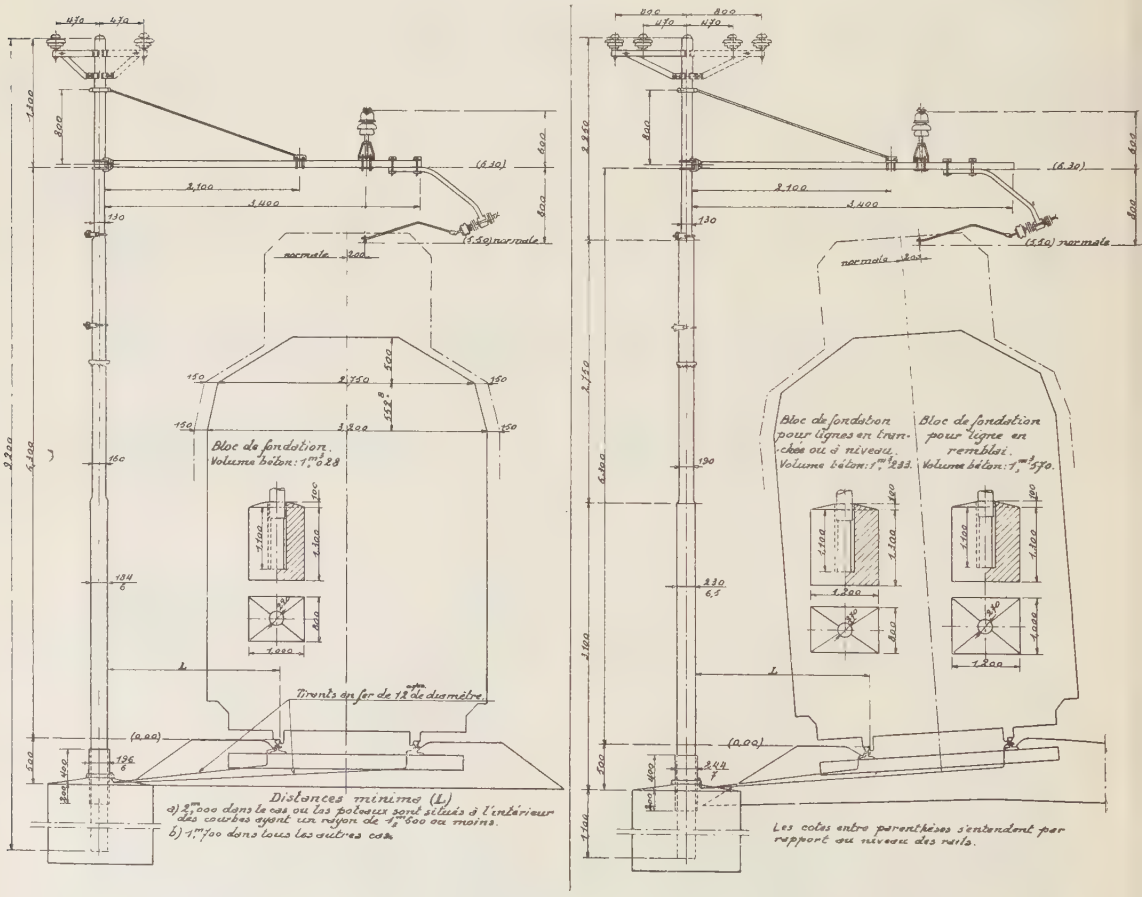

Bloc de fondation.
Volume béton: 1,m3 023
Tirants en fer de 12mm de diamètre
Distances minima (L)
a) 2,m000 dans le cas où les poteaux sont situés à l'intérieur des courbes ayant un rayon de 1,m600 ou moins.
b) 1,m700 dans tous les autres cas.
Bloc de fondation pour lignes en tranchée ou à niveau. Volume béton: 1,m3 233.
Bloc de fondation pour ligne en remblai. Volume béton: 1,m3 570.
Les cotes entre parenthèses s'entendent par rapport au niveau des rails.

Fig. 15. — Longitudinal suspension for 3 000-V. D.C. *(Italian State Rys.).*

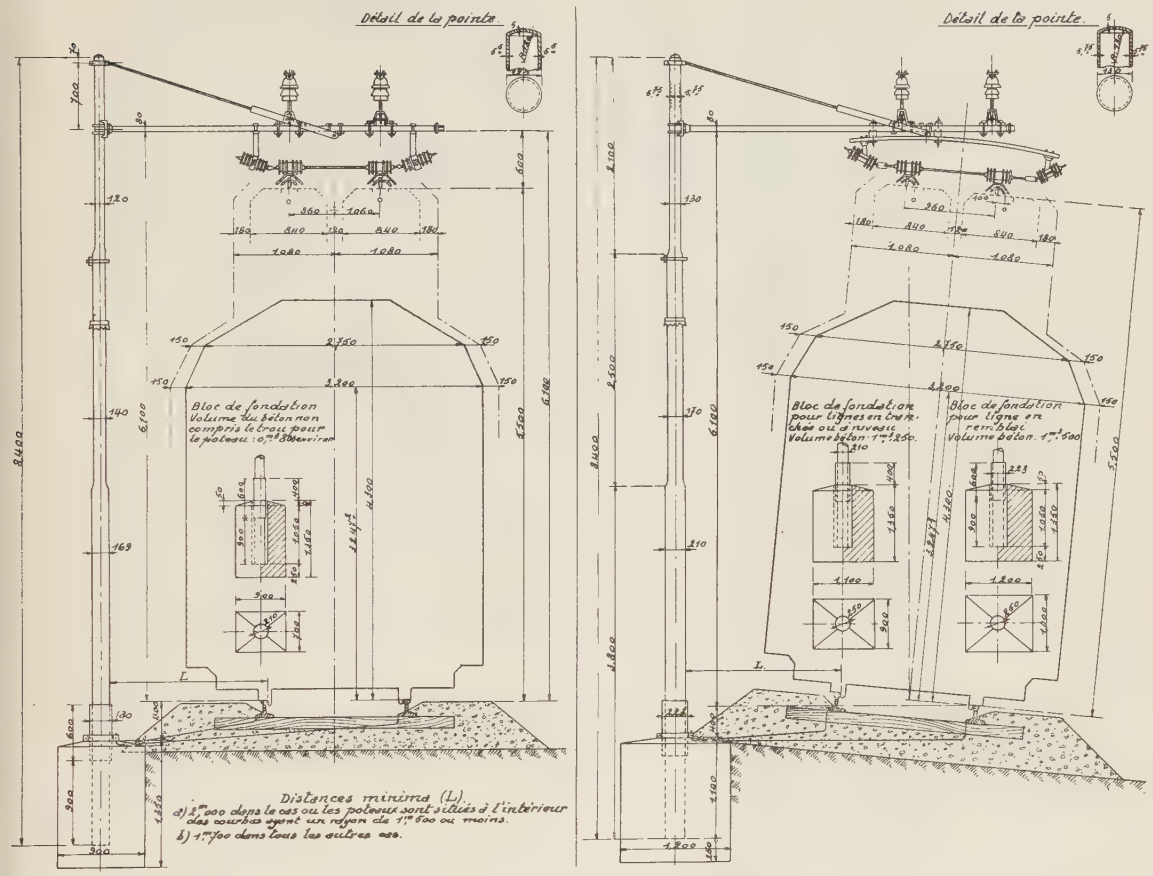

Détail de la pointe
Détail de la pointe
Bloc de fondation
Volume du béton en
compris le trou pour
le poteau : 0m³ 830 environ
Bloc de fondation
pour lignes en tran-
chée ou à niveau
Volume béton : 1m³ 250.
Bloc de fondation
pour ligne en
remblai
Volume béton : 1m³ 500
Distances minima (L)
a) 2m 000 dans le cas où les poteaux sont situés à l'intérieur
des courbes ayant un rayon de 1m 500 ou moins.
b) 1m 700 dans tous les autres cas.

Fig. 16. — Longitudinal suspension for 3 700-V. 3-phase, 16 2/3 cycle current
(Italian State Rys.)

The *French State Rys.* use trellis supports made of rolled steel sections.

The *Algerian Rys.* on 1/3rd of their lines use supports consisting of large-flanged joists, and on the remainder cross-braced girders.

The feet of the supports are usually buried in concrete foundations (see figs. 15, 16, 17).

In bad soil, the *Italian Rys.* use foundations carried on piles. The *French Rys.* in such cases increase the base area or use articulated gantries instead of brackets. The foot of the uprights is bolted to the foundation so that their position can be adjusted by lengthening the anchor bolts, and increasing the depth of concrete on top of the foundation.

Painting.

The supports are generally repainted every 4 to 5 years.

The *P.L.M.* applies two coats of red lead, then two coats of anti-rust metal paint.

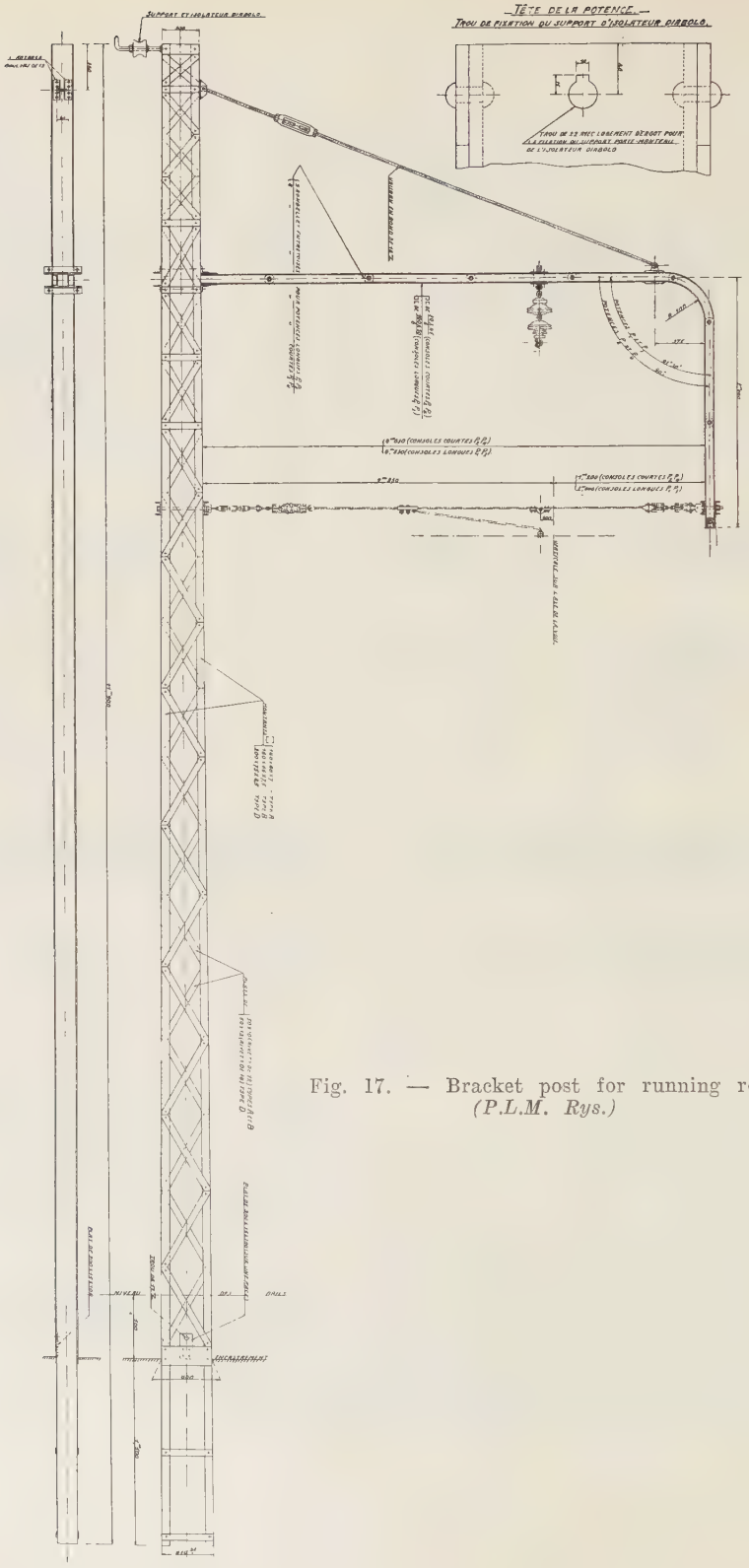


Fig. 17. — Bracket post for running road
(P.L.M. Rys.)

The *French State* and *P.O.-Midi* use galvanised parts near the catenary.

The Railways with which we are dealing here contract out the painting work.

Tests of spray painting in the case of metal supports have been carried out on the *Paris-Orléans Ry.*, but the method has been given up.

The use of metal spray for protecting supports has not been reported by any of the Companies.

Safety precautions during maintenance work.

As a rule the painting that has to be done with the contact line alive or dead is laid down in special regulations.

On the *P.L.M.* notices lettered : « Not to be operated—Work in progress on the line » are put on the circuit breakers. Portable earthing gear is put on the contact line on each side of the section where painting work is in progress. In any case the substation is not allowed to put on current without being asked to do so by telegram.

To sum up, maintenance work is carried out by special staff generally under the permanent-way department, responsible for maintaining the whole of the overhead equipment.

The supports are in steel trellis girder, tubular or wide-flanged joists or girders. The latter type has the advantage of being much easier to maintain and takes up less room.

The usual practice is to repaint the metal structures by contract every five years; mechanical means for removing the paint and spray painting are generally not resorted to.

Galvanised metal is used on parts near the catenary under tension. As practically no maintenance is required the additional first cost is made good.

No Railway reports the use of metal spraying for protection parts near the wires.

[621. 43]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

13th SESSION (PARIS, 1937).

QUESTION IV.

Evolution of the rail motor car

as regards its construction, and special investigation into the transmission and brake questions.

Comparative methods of testing railcars.

Detailed investigation into the costs of railcars and the methods of reducing them.

REPORT

(Germany, Austria, Bulgaria, Denmark, Egypt, Finland, Greece, Hungary, Norway, Poland, Rumania, Sweden, Switzerland, Czechoslovakia, Turkey, Jugoslavia),

by Herr STROEBE,

Reichsbahndirektor, Reichsverkehrsministerium, Berlin.

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Preface.

The present report completes the extensive report drawn up in 1935 by Messrs. DUMAS and LEVY on rail motor cars with self-contained power plant (published in the *Monthly Bulletin of the International Railway Congress Association* for August 1935).

In order to avoid repetitions, only the important alterations made in the meantime and new designs will be mentioned. The tables have been dealt with in the same way. The report relates to the following countries : Germany, Austria, Bulgaria, Denmark, Egypt, Finland, Greece, Hungary, Norway, Poland, Rumania, Sweden, Switzerland, Czechoslovakia, Turkey and Jugoslavia, and is based on the particulars supplied by the railways in these countries in reply to the questionnaire sent out.

* * *

I. — General data with regard to new problems in rail motor car design (see Table I).

The requirements to be met formerly by rail motor cars have been made far more difficult by the ever-increasing needs of the operating department, as well as by the continually increasing demands made by the passengers.

In this respect the following points must be mentioned especially :

(*a*) greater passenger accommodation obtained by increasing the length of the units;

(*b*) ever higher speeds;

(*c*) improved brake efficiency;

(*d*) greater gradient climbing ability;

(*e*) control from longer distances and simpler couplings;

(*f*) better riding;

(*g*) improved heating and ventilation;

(*h*) improved inside finish and greater comfort for the passengers;

(*i*) reduced risk of fire.

As the measures required to meet the above demands increase the weight of the railcars and also appreciably increase the first cost, owing to the expenditure involved in perfecting new improvements, it is impossible to compare old and modern rail motor cars with each other as regards weight and cost without first carefully investigating the whole matter.

Furthermore, the requirements to be met by railcars differ much from one railway to another, owing to the geographical situation, density of population, etc. In simple cases, adequate and technically sound designs are already available. In such cases standardisation is also made easier. There are great difficulties, however, in the actual construction of rail motor cars when the requirements are ahead of the technical progress. This is also to be taken into account when examining the questions of working safety, capital cost and maintenance costs of rail motor cars.

During the last few years, a new problem has arisen in connection with the railcar, i.e. passenger transport in the densily populated regions, where there are many towns very near each other (for example in Germany, in the Ruhr District). The solution of this question presents many difficulties because the railcars, owing to the high speeds, must have quick acceleration and short braking distances, so that the mechanical equipment must be able to withstand the very high stresses set up during acceleration and braking. Moreover, the passenger accommodation (number of seats) must be adapted quickly to meet sudden rushes of traffic, and the passengers must be given improved facilities for getting in and out of the railcars by providing a greater number of doors.

Table I gives particulars of railcars built since the previous report appeared. As it would not be possible to give in this report a description of all new de-

signs, we can only refer to the articles published thereon in the technical press; the designs which appear to us to deserve a special mention have been described in Chapter VIII.

* * *

II. — Engines (see Table II).

The ever increasing requirements to be met by railcars point either to the installation of a larger number of engines or to an increase in the power of each single engine. In the most difficult cases it will be necessary to resort to both solutions.

The use of more engines increases in general the purchase cost per H. P. and also involves much greater expenditure for the control and transmission gear. In spite of this, in certain cases in which a more powerful engine would be sufficient, the distribution of the necessary power between several engines may be advantageous, because it may then be possible to adopt a type of engine possessing proved qualities, or to use horizontal engines so as to make better use of the room available inside the railcar. Furthermore the great advantage must not be overlooked that when several engines are provided, even if one fails, the railcar will still be able to move under its own power.

Railcar sets, composed of two or several articulated vehicles, are generally equipped with 2 engines located symmetrically at the ends of the set. The Danish high-speed rail motor trains have 4 engines, installed in pairs at both ends of the rake.

In the case of new four-wheeled railcars, the power is 100 to 150 H. P. per engine and sometimes more, and on the eight-wheeled cars, 200 to 450 H. P. (in Germany even up to 560 H. P.).

New types of engine, not mentioned in the previous report by Messrs. Dumas and Levy, are shown in table II in which the engines are arranged according to their nominal horse-power.

No internationally recognised definitions of « nominal » and « maximum » power have been established so far.

Various Administrations give the ratio between the maximum and the nominal power as 1.1 and 1.25, but others do not give the maximum power, and give as the nominal power that which can be demanded from the engine continually without any inconvenience. It would be desirable that an exact definition of these two values be agreed upon in the near future.

The use of diesel engines is constantly increasing. The following table shows the percentages of petrol engines and diesel engines in use at present in the countries covered by this report.

—	Carburettor engines.	Diesel engines.
	%	%
Germany	about 10	about 90
Austria	» 50	about 50, more in future.
Poland	» 6.3	...
Rumania	» 12	about 88
Czechoslovakia	» 27	» 73
Hungaria	» 20.7	» 79.3
Denmark	» 0	» 100
Norway	?	» 10

TABLE I.

Type. 1	Builder. 2	Number of units in service. 3	Horse-power. 4	Weight in working order (metr. t.). 5
	Austria.			
VT 2020	Grazer Masch. Fabr.	1	200	39.1
2021	Floridsdorfer.	1	120	12.0
2040	Simmering.	3	145	11.5
2041	»	2	210	23.5
2070	Grazer Masch. Fabr.	1	200	34.0
VT 10	Warchalowski.	1	75	14.7
11	»	2	100	22.4
12	»	3	150	34.0
20	Deutsche Werke, Kiel.	1	100	18.4
21	»	1	150	27.0
22	Grazer Masch. Fabr.	1	150	32.4
23	»	1	100	20.8
30	Rebuilt by Feder. Rys.	1	50	13.8
31	»	1	2 × 60	20.8
40	Simmering.	1	100	23.8
41	»	10	160	33.25
42	»	2	2 × 210	49.5
43	»	1	210	27.47
50	Renault.	1	110	27.0
60	Perl.-St. Pölten.	4	80	6.4
61	Austro-Daimler.	1	80	6.23
62	»	6	2 × 80	10.0
63	»	4	2 × 80	18.52
160	Perl-St. Polten.	1	44	3.4
70	Grazer Masch. Fabr.	10	300	29.0

Railcars.

Passengers carried seated. 6	Passengers carried standing. 7	Luggage carried (metr. t.). 8	Total weight (metr. t.). 9	Weight per metre of vehicle length (buffers excluded) (metr. t.) 10	Remarks. 11
... (1)	...	...	39.1	4.44	(1) Locom.
... (1)	...	...	12.0	2.39	...
... (1)	...	...	12.0	2.40	...
... (1)	...	1.0	24.5	2.45	...
... (1)	...	...	34.0	3.82	...
50	15	...	19.9	1.71	...
60	21	...	28.9	2.42	...
76	20	...	42.0	2.55	...
55	9	...	23.6	1.92	...
82	30	...	36.0	2.02	...
82	30	...	42.0	2.46	...
50	10	...	25.6	2.22	...
48	10	0.3	18.6	1.92	...
53	15	...	26.8	2.55	...
66	10	...	29.0	2.35	...
64	...	0.5	38.37	2.48	...
78	...	1.0	56.8	2.65	...
41	...	0.5	31.3	2.40	...
66	15	0.5	34.0	2.06	...
27	20	...	9.2	1.09	...
24	...	0.2	8.23	0.99	...
45	...	0.2	14.38	1.27	...
74	...	0.4	25.3	1.07	...
1	...	...	5.4	0.99	...
... (1)	...	0.5	29.5	3.64	...

TABLE

Type.	Builder.	Number of units in service.	Horse-power.	Weight in working order (metr. t.).
1	2	3	4	5
		Hungary.		
4-wheeled, BC class.	Ganz & Co., Budapest.	74	108	19.7
6-wheeled, BC class.	»	42	108	21.0
Bogie railcars, BC class.	»	2	440	54.23
High-speed railbus.	»	4	220	35.15
...	...	...	...	...
		Jugoslavia.		
Small—light.	De Forenede-Automobilfabrik A./S. Odense-Denmark.	3	75	17.2
Large—heavy.		3	250	57.2
		Switzerland.		
CLm. 2/4 No. 101-102.	Winterthur Works.	2	290	~ 34.0
		Rumania.		
Diesel-electric.	« Astra » Works (formerly Weitzer), Arad.	9	90	18.5
		14	60	18.0
Sentinel-Cammell steam railcars.	« Sentinel-Cammell » Works. Nottingham and Shrewsbury (England).	2	200	61.88
		6	100	35.46
Petrol-mechanical. Vomag—T.A.G.	« Malaxa » Works.	...	110	20.0
Do.	»	...	110	20.0
Meadows.	»	...	115	21.3
Diesel-mechanical. Ganz.	« Malaxa » Works.	...	120	20.0
Do.	»	...	120	21.2
Do.	»	...	120	20.0

(continued).

Passengers carried seated. 6	Passengers carried standing. 7	Luggage carried (metr. t.). 8	Total weight (metr. t.). 9	Weight per metre of vehicle length (buffers excluded) (metr. t.) 10	Remarks. 11
45 or 46 passengers.	Not laid down (2).	Not laid down (2).	25.5 (3)	2.36	(2) 1 tip-up seat for guard.
»	Do. (2)	Not laid down (2).	26.22 (3)	2.43	(3) Including springs.
63	Do. (4).	Not laid down.	60.43	2.745	(4) 2 tip-up seats for driving staff.
64	8 tip-up seats (5).	1.0 (3) including springs.	42.07	1.91	(5) 2 tip-up seats for driving staff.
...	...	...	...	...	1 mobile seat for guard.
50	3	...	21.2	1.62	Length inside buffers : 10.60 m.
75	3 Standing not permitted.	1.0	63.8	3.17	Length inside buffers : 18.08 m.
65	35	~ 0.5	40.0	~ 1.8	...
39	10	1.0	23.3	1.94	Introduced before 1930 and still in service.
36	10	1.0	22.6	1.88	
114	20	2.5	72.92	2.24	Introduced after 1930.
55	12	1.5	40.24	2.26	...
2nd cl. 3rd cl. 20 + 20	...	...	...	2.22	...
19 + 24	...	...	...	1.96	...
29 + 29	...	...	...	...	...
18 + 25	...	...	...	1.96	I.A.R. 135 engine.
20 + 25	...	...	...	2.0	...
17 + 42	...	...	...	1.45	...

TABLE

Type.	Builder.	Number of units in service.	Horse-power.	Weight in working order (metr. t.).
1	2	3	4	5
	Rumania *continued*).			
M.A.N.-Mylius.	« Malaxa » Works.	...	150	21.2
M.A.N.-T.A.G.	»	...	150	21.5
M.A.N.-Mylius.	...	...	150	23.0
Ganz.	« Astra » Works.	...	120	20.0
»	« Unio » Works.	...	120	20.0
»	»	...	120	21.2
	Poland.			
8-wheeled (long runs).	H. Cegielski, Poznan (Poland).	15	300	32.0
8-wheeled (tourist).	I Locomotive Works, Poland.	6	250	22.0
8-wheeled (branch lines).	L. Zielencewski, Sanok (Poland).	3	220	36.9
8-wheeled do.	« Krolewska » & « Laura » Works (Poland).	1	420	47.9
4-wheeled do.	« Lilpop, Ran & Loewenstein » Warsaw.	11	100	15.8
8-wheeled do.	H. Cegielski, Poznan (Poland).	9	100	40.8
8 or 4-wheeled do.	Various.	9	100 + 220	19 ÷ 47.0
6-wheeled do.	Various.	40	90	29 % 33.0
	Denmark.			
Bogie railcars (See diagrams).	Frame : Skandia Co.	20 Class Mo.	2 × 250/275	∽ 58.3
	Renders, and Frichs, Aarhus.	10 Class MP.	...	« Lightning train » made up of 2 power coaches and 1 intermediate unit : 129.2.
	Bogies : Frichs, Aarhus.	8 Class Ms. Articulated «Lightning» train.	...	...
	Egypt.			
Single-eng. railcar, 1927.	Clayton & Co.	1	45	30.5
Articulated steam rc., 1928	»	5	150	46.1
Do. 1930	Birmingham Ry. Carr. & Wag. Co.	5	150	52.0
Do. 1930	»	6	150	52.5
Do. 1930	Sentinel-Cammell Co.	10	320-350	65.6
Diesel railcar 1935	Ganz & Co.	6	220-275	36.75

(continued).

Passengers carried. seated. 6	Passengers carried. standing. 7	Luggage carried (metr. t.). 8	Total weight (metr. t.). 9	Weight per metre of vehicle length (buffers excluded) (metr. t.) 10	Remarks. 11
20 + 25	...	...	...	2.0	Wbv 15/18 A. A. engine.
20 + 25	...	...	...	2.0	...
20 + 35	...	...	...	1.885	...
17 + 42	...	...	...	1.45	...
17 + 42	...	...	...	1.45	...
20 + 25	...	...	...	2.0	...
77	20	2.0	41.8	1.5	...
52	4	...	26.5	0.95	...
60	20	2.0	45.0	1.9	...
78	20	2.0	58.0	2.2	...
41	18	1.5	22.0	1.4	...
70	12	...	47.0	2.2	...
46 ÷ 80	÷ 20	2.0	...	...	...
45	12	...	...	...	...
64	...	1.3	~ 64.0	~ 3.22	...
Lightning train : 1st class : 36. 2nd class : 32.	...	...	Lightning train : ~ 140.0	~ 2.2	...
...	...	...	...	...	...
65	...	...	...	1.7	...
115	...	...	...	1.54	Rebuilt, equipped with Birmingham steam railcar engine.
109	...	...	...	1.74	...
111	...	...	...	1.75	...
114	...	...	...	1.98	...
70	...	...	...	1.68	...

The chief advantages of the diesel engines, as pointed out by nearly all countries, are their lower fuel consumption, hence lower working costs, as well as reduced fire risk, and their disadvantage, their harsher running. For the last mentioned reason, Czechoslovakia still uses carburettor fitted engines on four-wheeled railcars. In countries which will in future produce their own fuel synthetically, further progress will depend on the kind of fuel available.

Photographs of new types of engines are given in figures 1 to 11. The development of the engines points to a higher power of each single engine, and from the whole power plant. Engines up to 600 H. P. are already in use, and engines developing up to 1 300 H. P. are under construction. The 600-H. P. engines can — although with difficulty — still be carried on the bogies ; the higher powered engines are carried on the underframe of the vehicles.

No outstanding innovation can be reported in connection with carburettor fitted engines.

As to the diesel engines, the former practice of direct injection of the fuel into the cylinders is being abandoned in favour of special chambers, mostly precombustion chambers.

The cylinders are usually in line in engines up to about 200 H.P., but for engines of higher horse-power the V engine is preferred. The most common numbers of cylinders are 6 and 12, and less frequently 8.

Several Administrations are carrying out trials with horizontal engines, the chief advantage of which is that better use can be made of the available room in the railcar. The development of these

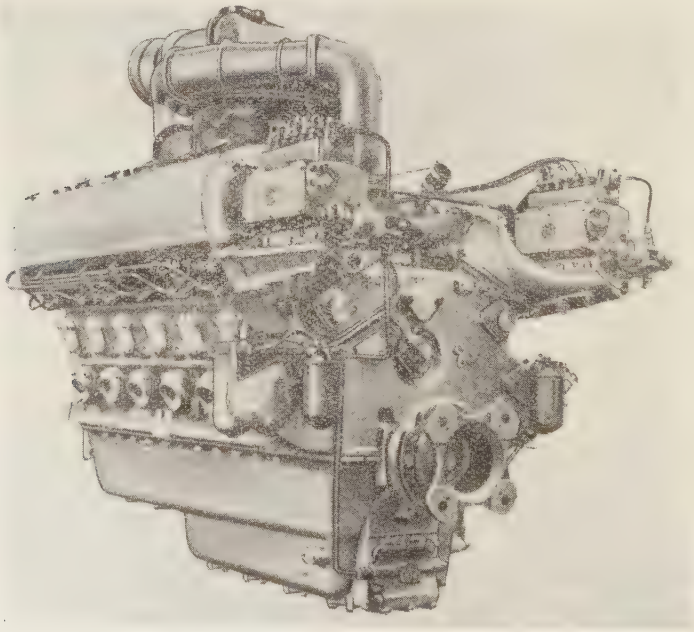

Fig. 1. — *Maybach G. 06* 12-cylinder, 600-H.P. 1400-r.p.m. supercharged engine.

TABLE 2. — Engines in service or under construction, which are not included in Table I of Report on « Rails motor cars from the point of view of their construction » (*Bulletin of the Railway Congress*, August 1935) - arranged according to their horse power.

Seq. No.	Engine: Builder	Taken over from Saar District.	Cont.	Maxi.	Rpm.		Weight:	Wet measure	No. of cylinders	Cylinder: V-type...	Bore	Stroke	Swept volume (cmb): cylinder	total	Mean piston speed	Mean pressure	Fuel consumption, gr. per H.P.-hour: half load.	full load.	Method of ignition and injection compressor: injection pump, direct with mechanic. with or without supercharging etc.	System of: injection pump.	nozzles.	Bearings of Crankshaft: Numbers	Rod, ex. plain bearings roller bearings	Connecting rods: Big end bearings plain bearings.	Small end bearings roller bearings ball bearings.	Materials: Pistons	Rods	Crankshaft				Governing			Weight per H.P.		Seq. No.
1	2	3	4	5	6		7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	1
1	Ford.	Taken over from Saar District.	8	40	...	...	2 200	...	...	...	...	...	...	...	...	...	...	...	Carburettor.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2
2	Deutz.		8	50	...	...	2 350	...	...	...	...	...	...	...	...	...	...	...	Diesel eng.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3
3	N.A.G.-Kl 10 Z.	Germany.	11	70	...	...	3 500	...	...	...	120	170	2 143	14 000	...	...	...	250	Carburettor (Pallas)	...	...	...	Plain.	Plain	Bushes	Cast iron	Steel.	Steel.	Cast iron	Cast iron	Aluminium	Mechanic.	1 400	620	980	1	3
4	Hesselmann type.	Suecia.	7	75	600	700	3 500	800	10.6	6	»	105	136	1 474	7 066	9.07	...	...	260	Direct injection.	Piston pump.	...	7	»	»	»	Cast iron. Brinell 220	Steel, tens. 80 kgs/mmc	Nickel-chromium steel.	Aluminium alloy.	Cast iron.	Mechanic.	1 400	718	1 060	2	4
5		Buessing.	9	90	115		2 400	2 200	6.6	6	»	111	140	1 340	8 040	9.3	5.0	320	280	Carburettor.	...	...	7	»	»	Bronze bushes.	Aluminium alloy	C N R	Nickel-chrome steel	Aluminium alloy									5
6	Henschel.	Germany.	3	100	...	...	1 500	...	...	...	»	...	...	...	...	...	...	...	»	...	...	...	...	...	...	...	Cast iron.	Nickel-chrome steel.	Nickel-chrome steel.	Light metal.								6
7												94	168	1 163	6 980				235	Carburettor (Maybach)	Bosch-Battery ignition.		...	...	...	...	...											7
8												110	150	1 427	8 550				185	Injection pump.	Simba.			Roller	»		Alloy.	Special steel.	Special steel.	Alloy.	Bronze alloy and cast iron.						8
9	Ganz-Jendrassik VI Jm R 150.	Hungaria.	25	108	120	700	1 000	1 100	1	6	»	150	185	3 870	19 650	6.47	5.0	320	195	Injection pump. Antechamber.	Ganz-Jendrassik.		4	Plain.		Bronze bushes	Special iron.	Nickel steel	Nickel-chrome steel	Special iron	Steel.	Cast iron.	2 400	750	1 150	2	9
10												125	160	1 960	14 750				250	Carburettor (Zenith)	...	...	...	»	»	»	Light metal	Steel	Steel.	Cast iron.	Cast iron.						10
11	Csonag.	Rumania.	15	110	...	...	1 500	2 000	22	5.5	1	130	160	2 120	12 720	8.0	5.18	320	280	Carburettor (Pallas)	...	...	6	...	»	...	Aluminium alloy	V C N	Nickel-chrome steel	Aluminium alloy				1 500	700	1 240	1	11
11a	Buda GF-6. (Petrol-engine).	Norway.	49	...	120	400	...	1 600	615	5.4	6	»	120.65	152.40	1 750	10 500	8.4	...	350	295	Electric ignition. Norway carburettor.	...	...	4	Plain. white metal.	Bronze.	Bushes. white metal.	Cast iron.	Steel.	Steel.	Silumin.				2 455	700	1 600	1	11a
11b	Mercedes-Benz O.M. 54. diesel-engine.	Norway.	8	...	135	500	...	1 700	1 000	7.4	6	»	125	170	2 080	12 500	9.0	...	...	200	Bosch injection pump. Antechamber with heating plugs (no supercharg.).	Bosch PE.	Bosch DN4 SD20	7	Plain. lead-bronze.	»	Plain bearings, lead-bronze.	Light metal.	»	»	Light metal.				1 580	700	1 175	1	11b
11c	Gebrüder Sulzer.	Switzerland.	...	...	...	...	...	...	...	...	...	135	180	2 650	15 900	8.0	5.23	240	185	Antechamber injection pump.	Ganz.	Ganz	7	lead-bronze with white metal		Phosphor-tin bronze bushes	Cast iron	Special steel 1.5 % nick	Aluminium steel	Cast iron				1 2555	998	1 450	1	11c
11d	Ganz-Jendrassik VI Jak 150.	Hungaria.	...	150	165	600	1 500	1 600	1 600	10.7	8	V-type.	130	160	2 123	16 984	8.0	5.3	225	185	»	Bosch PE4B. 80 B/200.	Bosch, nozzles with obturating pin. DN4 SI.	5	Plain. Special lead-bronze.	Bushes : Carobronze.	Plain bearings, special lead-bronze.	Special light metal.	Nickel-chrome steel (improved).	Chr.-molyd. steel (improved).	Silumin.	Steel, nitrid. Lower part of piston with cast iron.	Duralumin with steel ring.	Cast iron.	Cast iron.	Cast iron.	Cast iron.	1 700	1 200	1 400	1	11d
11e	Masch. u. Waggonbaufabrik A.G. Simmering.	Bulgaria.	...	150	165	600	1 500	1 600	1 600	10.7	8	V-type.	130	160	2 123	16 984	8.0	5.3	225	185	»	Bosch PE4B. 80 B/200.	Bosch, nozzles with obturating pin. DN4 SI.	5	Plain. Special lead-bronze.	Bushes : Carobronze.	Plain bearings, special lead-bronze.	Special light metal.	Nickel-chrome steel (improved).	Chr.-molyd. steel (improved).	Silumin.	Steel, nitrid. Lower part of piston with cast iron.	Duralumin with steel ring.	Cast iron.	Cast iron.	Cast iron.	Cast iron.	1 700	1 200	1 400	1	11e
12	Simmeringer Maschinenfabrik — SV 8.	Austria.	1	140	154	550	1 500	...	1 700	12.2	8	V-type.	130	160	2 120	16 960	8.0	4.95	...	...	Bosch inject. pump. Antechamber; nozzles with obturating pin.	Bosch PE 4 B 80 B/200	6-1.5	5	»	»	»	»	Styria nickel-chrom steel. Improved N H 3.	B.S.E. duro special steel.	Cast iron.	Cast iron				1 800	1 140	1 470	1	12
13	Saurer.	P.Z. Jaz. (Poland).	...	150	165	560	1 350	1 500	1 100	...	6	in line.	130	180	2 380	14 340	...	5.6	...	180	Injection pump.	Bosch.	...	...	Roller.	»	»	Alloy.	Special steel.	Special steel.	Alloy.	Special cast iron liners.							13

TABLE II *(Continued).*

No.	Builder	Remarks	Number of cylinders	Normal power (metric h.p.)	Revolutions per minute	Weight per h.p. (kg.)	Number of cylinders	Cylinder arrangement in line, V-type, etc.	Bore. (mm.)	Stroke (mm.)	Swept volume (cm³) per cylinder.	Swept volume (cm³) total.	Mean piston speed (m./sec.)	Mean pressure (kg./cm²)	Fuel consumption gr. per h.p./hour. half load.	Fuel consumption gr. per h.p./hour. full load.	Method of ignition and injection (compressor, injection pump, direct, with antechamber, with or without supercharging, etc.	System of injection pump.	System of nozzles.	Bearings of Crankshaft. Number.	Bearings of Crankshaft. Kind, e.g. plain bearings, roller bearings.	Bearings of Connecting rods. Big end bearings, plain bearings.	Bearings of Connecting rods. Small end bearings, roller bearings, ball bearings.	Materials. Pistons.	Materials. Rods.	Materials. Crankshaft.	Materials. Casing.	Materials. Cylinders.	Lubrication.	Starting.	Fuel admission.	Specific weight of engine (kg./h.p.)	Specific fuel consumption (gr./h.p./hour)	Specific oil consumption (gr./h.p./hour)	No.
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
14	Simmering-WK Maschinenfabrik.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	140	180	[illegible]	[illegible]	[illegible]	[illegible]	215	190	Direct. Bosch injection pump. Central nozzle.	Bosch PF 4 B 90 A/202	Ø 0·1·5	5	Plain.	Babbit. Antechamber.	Bearing metal.	Aluminium alloy.	Bohler improved, auto extra nick.-chr. steel.	Special steel.	Steel plate.	Steel liners.	»	»	[illegible]	1·37	1 500	1 125	13
15	[illegible]	[illegible]	[illegible]	160	175	480–500	1 200	1 350	1 850	14·55	8	4 + 4 horizontal.	150	180	3 180	25 400	7·2	4·73	213	198	Antechamber.	Bosch.	Ø 2/6	5	»	»	»	»	»	»	»	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	15
16	Skoda-yard-only.	»	..	160	180	550	1 600	1 700	1 700	7·5	8	4 + 4 horizontal.	125	160	1 963	15 740	9·53	6·43	225	205	Turbulence chamber.	»	Ø 2/7	5	Roller.	»	»	»	»	Nickel-chrom steel.	Cast iron.	Nickel iron.	»	»	[illegible]	1 400	2 554	650	16
17	[illegible]	Germany.	5	165	180	...	...	1 500	1 910	10·6	8	horizontal in line.	135	180	2 580	20 600	9·0	5·2	192	247	Inject. pump. No compressor. Turbulence chamber. No supercharging.	»	Bosch.	...	Plain.	»	»	Light metal.	...	Double duro hardened steel.	...	...	»	»	[illegible]	[illegible]	[illegible]	[illegible]	17
18	[illegible]	Austria. Poland.	2 ..	240 ..	... ..	500 800	1 350 1 350	... ...	2 400 2 800	11·4 ...	8 8	V-type. »	150 150	190 190	3 340 3 350	26 720 26 800	8·6 ...	5·72 5·3	226 ...	190 185	Antechamber. Nozzles with oblurating pin. Bosch inject. pump.	Bosch PE 4 B 100 C 200	6-1.5	5	»	»	»	Aluminium alloy.	Bohler improved, auto extra nick.-chr. steel.	Special steel B.S.F. duro chrome-molybd.	Cast iron.	Cast iron liners.	»	»	[illegible]	[illegible]	[illegible]	[illegible]	18
19	[illegible]	[illegible]	[illegible]	240	252	700	1 200	1 320	2 200	10·5	8	V-type (90°).	150	190	3 340	26 720	8·35	5·34	228	188	Antechamber.	Bosch.	Ø 2/6	5	»	»	»	»	Treated steel.		Upper part: cast iron. Lower part: light metal.	Cast iron.	»	Electr. by generator.	[illegible]	[illegible]	[illegible]	19
20	Burmeister & Wain.	Jugoslavia.	3	250	260	540	720–1 000	1 100	2 000	7·3	6	in line.	150	220	3 883	23 344	7·33 at 1000 r.p.m.	...	...	200	Direct injection.	Piston pump.	...	...	...	...	...	Perlitic iron.	Siemens-Martin steel.	S M steel.	[illegible]	Cast iron.	[illegible]	[illegible]	[illegible]	[illegible]	20
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8·8	[illegible]	[illegible]	185	260	[illegible]	[illegible]	[illegible]	[illegible]	199	165	Injection pump.	Bosch.	...	...	...	...	Bushes.	Aluminium.	Steel.	...	Alloy steel.	...	»	[illegible]	[illegible]	[illegible]	21
22	Daimler MB 401 Deutz A 12 M 316 Deutsche Werke, Kiel 12 V 19 M.A.N.-W 12 V 22/30.	Germany.	4 each	...	275	500	...	1 560	2 200	8	12	horizont. opp. cyl. each 6 cyl. in line.	130	190	2 517	30 200	9·5	5·5	...	...	Injection pump. No compressor. Antechamber.	»	Bosch.	...	Plain.	»	»	Light metal.	Special steel.	Double duro chr.-molybd. hardened steel.	...	...	»	»	[illegible]	[illegible]	[illegible]	[illegible]	22
23	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	23
24	Sulzer.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2 400	7·45	6	in line.	190	230	6 500	39 000	9·2	5·6	187	214	Direct injection. No supercharging.	»	Sulzer.	7	»	»	»	Aluminium.	Nickel-chrome steel.	S M steel.	Silumin.	...	»	[illegible]	[illegible]	[illegible]	[illegible]	24
25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	»	Bosch.	7	»	»	»	Light metal.	Special steel.	Double duro chr.-molybd. hardened steel.	Cast iron.	...	»	[illegible]	[illegible]	[illegible]	[illegible]	25
26	M.A.N. W 6 V 22/30.	Germany.	30	360	400	...	870	900	...	...	6	»	220	300	11 400	68 400	8·7	...	...	...	[illegible]	»	Bosch.	7	»	»	»	Light metal.	Special steel.	Double duro chr.-molybd. hardened steel.	Cast iron.	...	»	[illegible]	[illegible]	[illegible]	[illegible]	26
27	Maybach (GO 56).	»	17	410	...	800	1 400	...	2 100	5·1	12	V-type.	160	200	4 020	48 240	9·33	5·47	...	185	Direct injection.	Deckel pump.	Deckel nozzles.	7	Roller.	Roller.	»	Aluminium alloy.	»	Special steel.	Light metal.	Cast iron.	»	[illegible]	[illegible]	[illegible]	[illegible]	27
28	M.A.N. (L 12 V1.	»	3	420	...	700	1 400	...	2 900	6·9	12	»	175	180	4 330	51 960	8·40	5·22	...	197	Antechamber.	Bosch.	Bosch.	...	Plain.	Plain.	»	»	»	»	Cast iron.	»	»	[illegible]	[illegible]	[illegible]	[illegible]	28
29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3 560	6·3	12	»	175	180	4 330	51 960	8·40	6·95	...	190	Direct injection. Supercharging.	M.A.N.	M.A.N.	2 crank-shafts.	»	»	»	»	»	Steel plate.	Steel.	»	[illegible]	[illegible]	[illegible]	[illegible]	29
30	M.A.N. [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	with super-charger. 2 400	4·0	12	»	160	200	4 020	48 240	9·33	8·00	183	180	»	Deckel pump.	Deckel nozzles.	7	Roller.	Roller.	»	»	»	»	Light metal.	Cast iron.	»	[illegible]	[illegible]	[illegible]	[illegible]	30
31	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	31
32	M.A.N. W 8 V [illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	with super-charger. [illegible]	7·7	8	in line.	300	380	26 800	214 400	8·86	7·75	...	165	Direct injection. Supercharging.	M.A.N.	M.A.N.	9	Plain.	Plain.	»	»	»	S M steel.	Upper part: cast iron. Lower part: steel plate.	»	»	[illegible]	[illegible]	[illegible]	[illegible]	32

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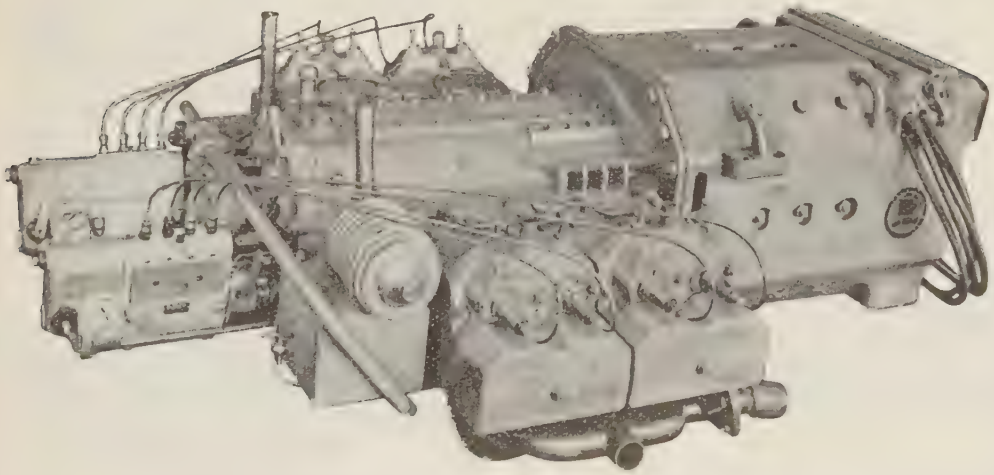


Fig. 2. — *Skoda* 8-cylinder, 160-H.P., 1600-r.p.m. horizontal engine.

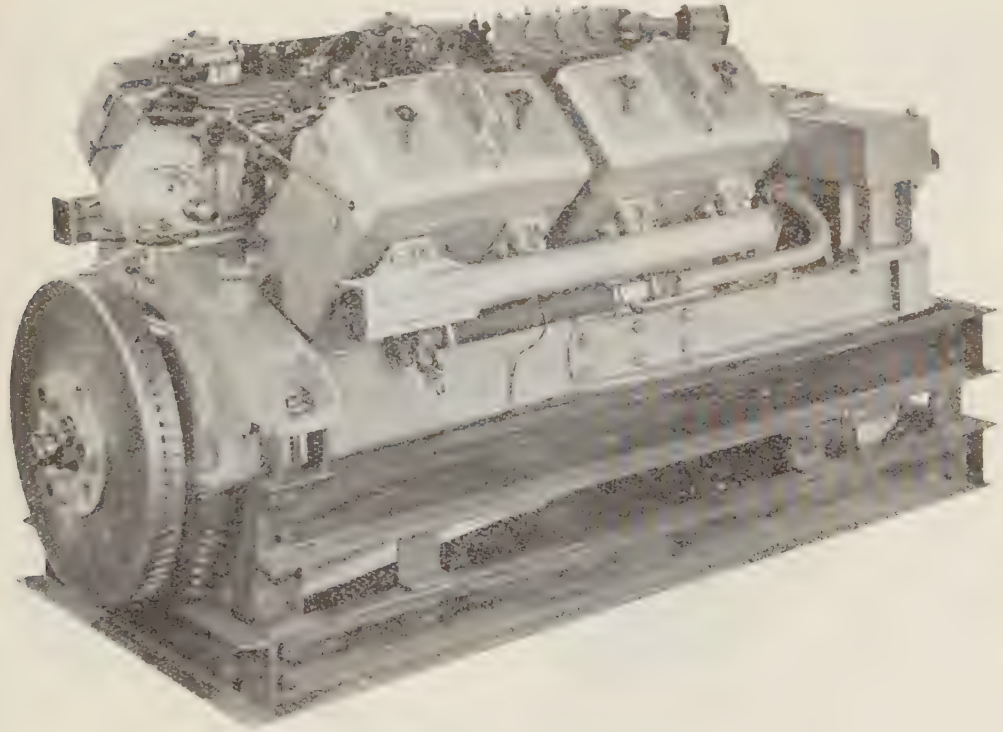


Fig. 3. — RS 8-cylinder, 210-H.P., 1250-r.p.m. engine of the *Maschinen und Waggonfabrik*, Wien-Simmering.

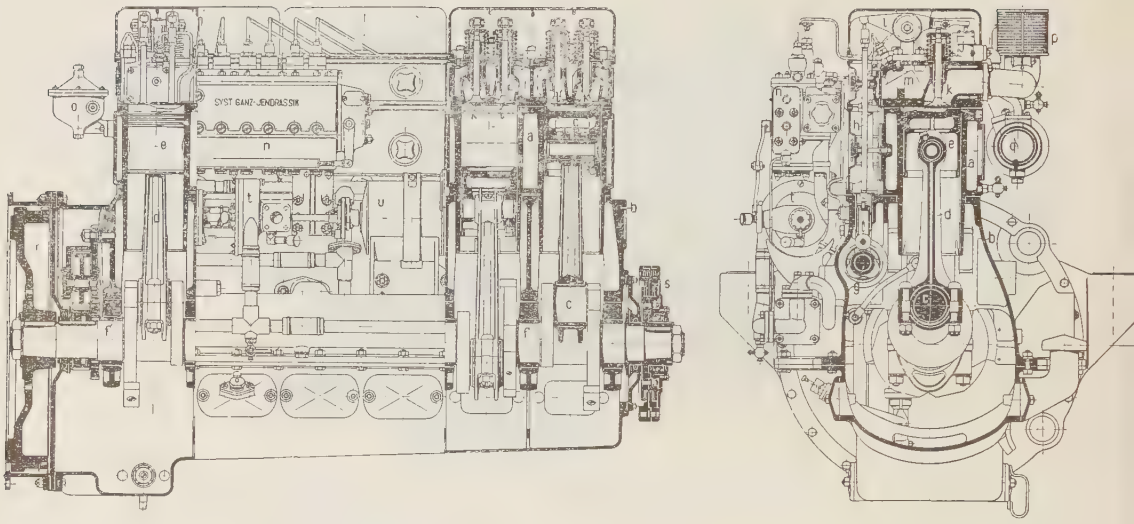


Fig. 4. — Elevation and cross section of a type VI. JaR 135, *Ganz-Jendrassik* railcar engine.

a. Cylinder block.
b. Crank case.
c. Crank shaft.
d. Connecting rod.
e. Piston.
f. Crank shaft bearing.
g Cam shaft.
h. Valve tappet.
i. Valve rocker.
j. Device taking up play between valve tappet and valve rocker.
k. Suction valve.
l. Exhaust valve.
m. Precombustion chamber with injector.
n. Fuel pump.
o. Fuel oil filter.
p. Air filter.
q. Exhaust pipe.
r. Flywheel.
s. Vibration damper.
t. Cooling water pump.
u. Lighting dynamo.

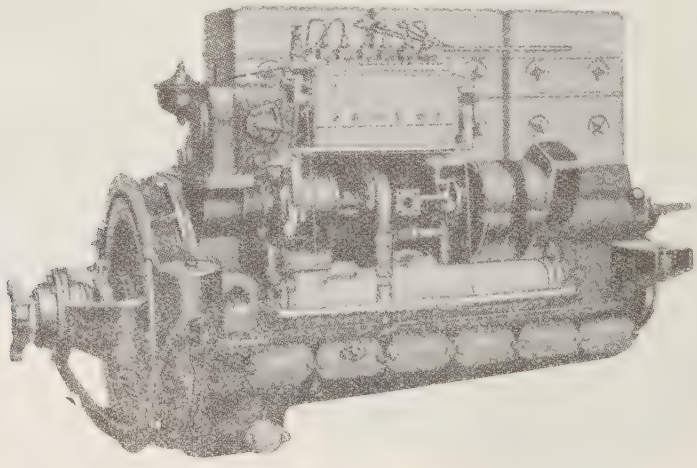


Fig. 5. — *Ganz-Jendrassik* type VI JaR 135 railcar diesel engine.

Nominal power : 120 H.P. at 1300 r. p. m.
Maximum power : 165 H. P. at 1500 r. p. m.

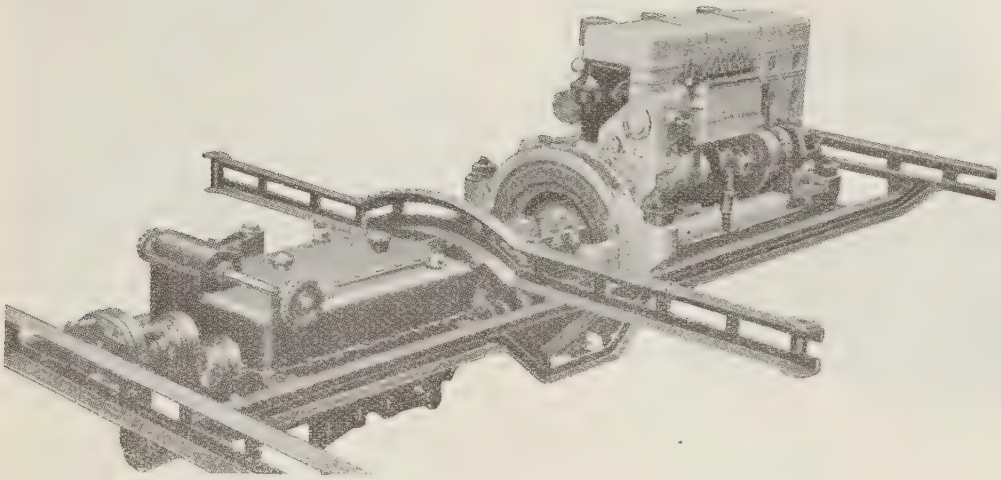


Fig. 6. — *Ganz-Jendrassik* diesel engine with gearbox.

engines is making great progress. In addition to the already well known *Czesco-Morawska Kolben-Danek* 150-H. P. and *Skoda* 120-H. P. types, built in Czechoslovakia, and the 180- H. P. engine of the *Deutsche Werke*, at Kiel (see *Bulletin of the Railway Congress*, August 1935, p. 902), new 275-H.P. engines have been built by 4 different German firms (*Deutsche Werke*, Kiel ; *Humboldt-Deutz Moto-*

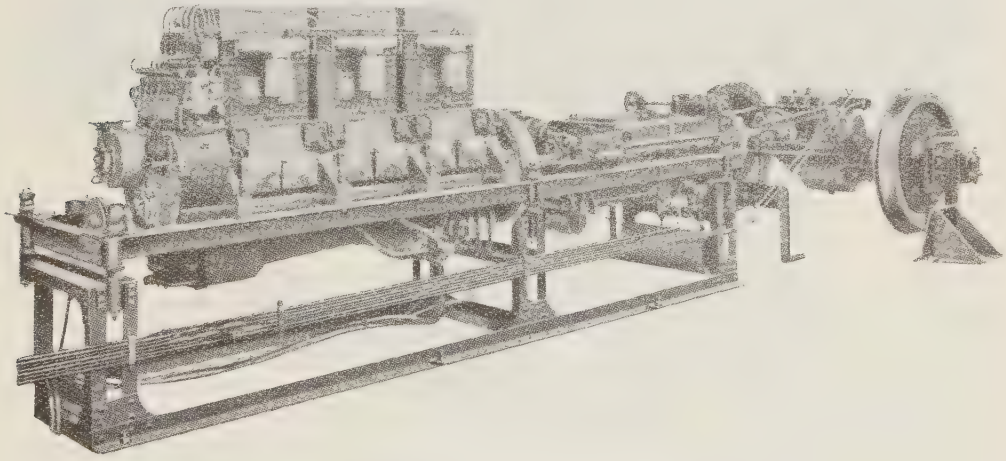


Fig. 7. — *Ganz-Jendrassik* type VI JmR 150 railcar diesel engine with mechanical transmission.

Nominal power : 110 H. P. at 1000 r. p. m.

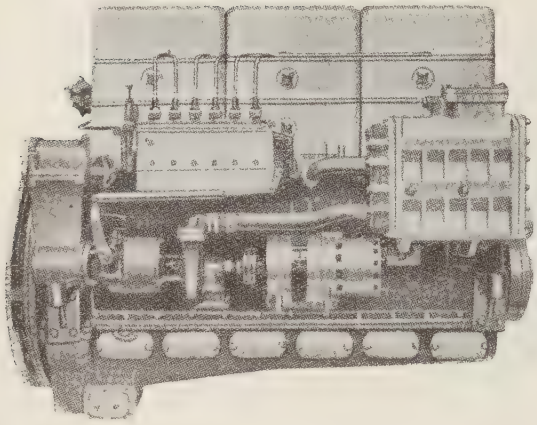


Fig. 8. — *Ganz-Jendrassik* type VI JaR 170 diesel-engine for railcars.

Nominal power : 220 H. P. at 1200 r. p. m.
Maximum power : 275 H. P. at 1450 r. p. m.

renbau at Cologne-Deutz; *Daimler Benz A.G.*, Stuttgart-Untertürkheim; *Maschinenfabrik - Augsburg - Nuremberg)*, some of which are already in service. When designing these engines, apart from specifying the same engine power and speed (r.p.m.), the Reichsbahn in order to obtain interchangeability, laid down that all the dimensions of parts to be assembled should correspond and that the auxiliary equipment, such as the fuel pumps, the starters, and filters, should present standardized features. This object has been attained by all the firms concerned (see figs. 12 to 14).

Insufficient experience has been obtained with horizontal engines to express any definite opinion but so far they have been satisfactory. Czechoslovakia reports a particularly heavy lubricating oil

Fig. 9. — *Ganz-Jendrassik* type VI JaR 170 diesel engine in a fast railcar bogie with gearbox and radiator.

consumption with these engines (35 kgr. per 100 km. = 112 lb. per 100 miles for 160 H. P.); furthermore a number of cylinder heads have cracked.

As the construction of the engines is still under development, the endeavours made in various countries to *standardise* them have not been successful as yet. It appears, however, that *Hungary* has made much progress already in this respect.

It is significant that countries owning engine works, try to push their own products to the fore. Under such conditions, the smaller the number of works to be taken into consideration, the easier it is to standardise.

The opinions in the various countries still differ on the best combustion process. Precombustion-chamber engines seem to gain ground on account of their

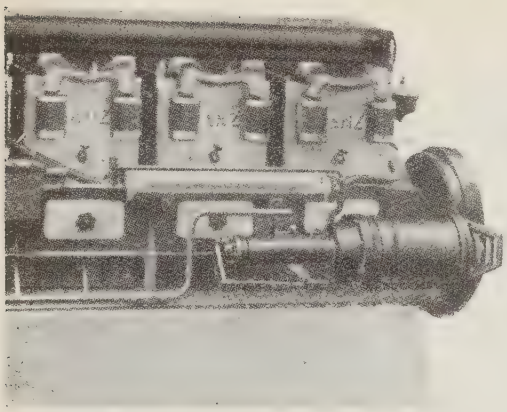


Fig. 10. — Engine with pneumatic starter.

smoother running, better combustion at all speeds, comparatively low injection pressure, and lower maximum working pressures. This means less difficulties with the bearings. A very important feature too is that the precombustion chamber engines can be easily adapted to lignite tar oil consumption.

Supercharged engines have only been introduced in limited numbers, but so far have given good results. It is, of course, not yet possible to form any definite opinion on this practice.

In this connection, Germany has had very good results from 600-h. p. Maybach engines and 560-h. p. M.A.N. engines. In both cases the B.B.C. turbo-blower is

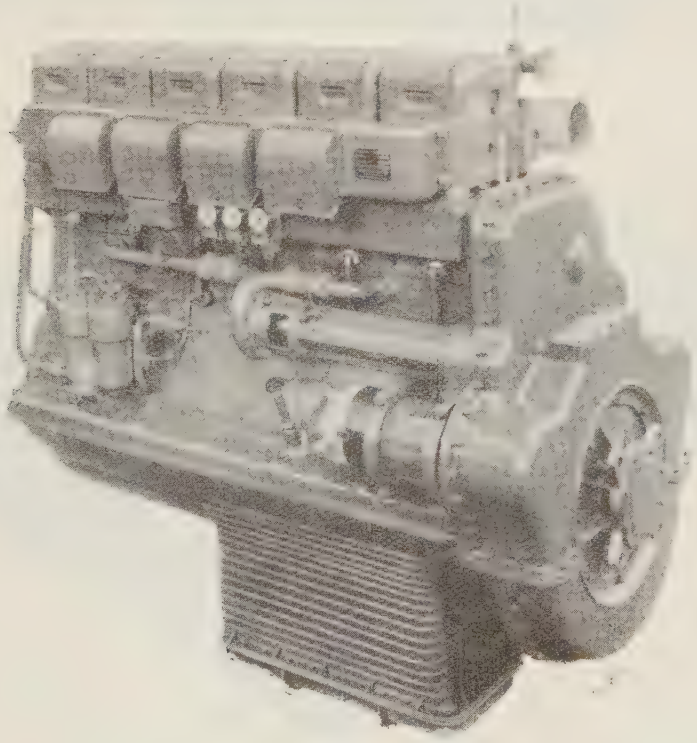


Fig. 11. — *Sulzer* 290-h.p. 6-cylinder 1200-r.p.m. engine.

Fig. 12.

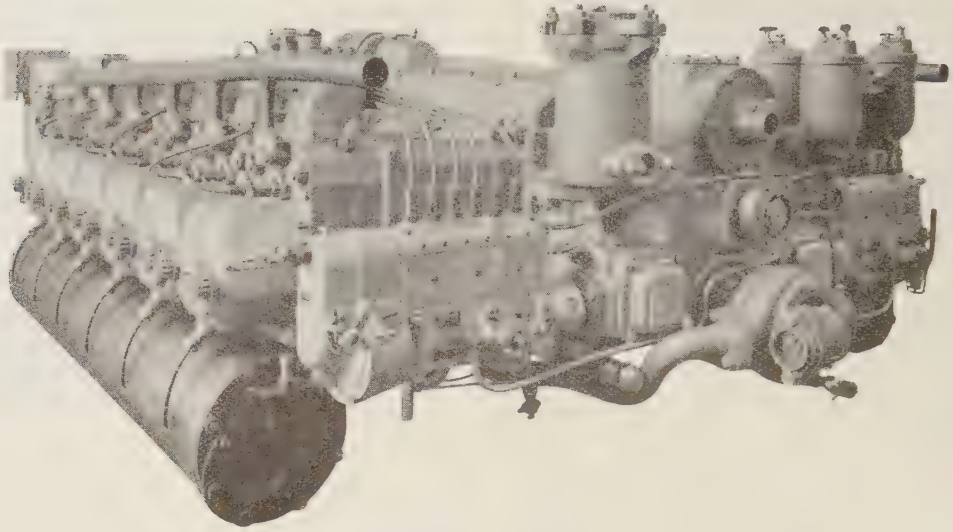
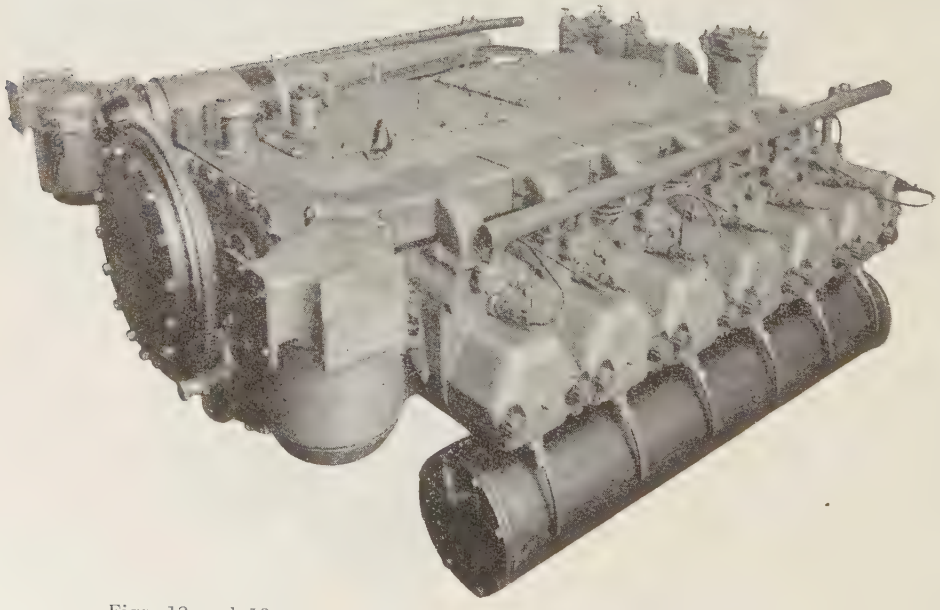


Fig. 13.



Figs. 12 and 13. — 12 V 19, 275-H.P. engine, *Deutsche Werke*, Kiel.

Bore : 130 mm (5 1/8"). Stroke : 190 mm. (7 1/2"). 1500 r. p. m.

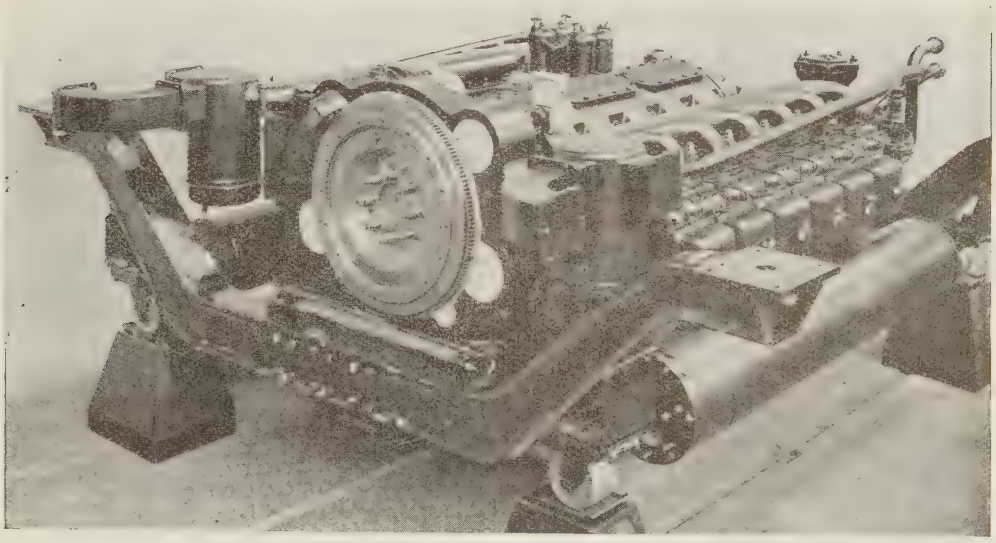


Fig. 14. — *Humboldt-Deutz* 275-h.p. 12-cylinder 1500-r.p.m. horizontal engine.

used. A remarkable feature is that, in spite of the higher power per cylinder, the stresses in the motion are lower, and more uniformly distributed than with the same engines without supercharging. One particular advantage is the intense scavenging effect obtained with supercharging and the resulting lower temperature of the pistons and cylinder walls due to better cooling. The thermic stresses in the constructional materials used for the engines are reduced to an appreciable extent.

Poland uses « *Ebermann* » engines, supercharged on the « Wihu » system, with good results.

Two-stroke engines have not been used so far by any of the Railways with which we are dealing. Hungary reports that two-stroke engines are not used because their fuel consumption is excessive.

Trials with the so-called substitute fuels have only been made in countries dependent on imported fuels.

In *Germany* trials of oils distilled from lignite tar have been made, without any alteration being made to the engines. No reduction has been noticed in the power of the engines as compared with that developed when using normal fuel. The fuel consumption (related to 10 000 calories = 3 970 B.T.U.) remained the same. Railcars with M. A. N. type W6 15/18 engines using lignite tar oil have been in service a few months. No failure has occured so far. On the other hand, the passengers object to the disagreeable smell of the lignite tar oil. This smell is given off by the oil when exposed to the atmosphere, so that the greatest care must be exercised when filling the tanks and the engine compartment must be shut off from the passenger compartments as effectively as possible.

In *Czechoslovakia,* a railcar has been designed to use producer gas and has given good results so far. Alterations, however, are being made at present in

the gas-producer and its accessories. Experience obtained in Czechoslovakia shows that the first cost, the maintenance and operating costs of this type of railcar are *higher* than in the case of vehicles with diesel engines. An advantage is the smoother running as compared with diesel engines — oscillations and noise being about the same as with carburettor-fitted engines.

The average piston speed of modern engines is 9 to 9 1/2 m. (29.5′ to 31.2′) per second, and in one case 10 m. (32.8′) per second.

The pistons are nearly always made of light alloys, a practice with which great experience is necessary both as to the composition of the metal used and as to the machining conditions.

The best results have obtained with silicon-aluminium alloys, such as E.C. 124 (Elektron Cannstadt) or K.S. 1275 (K. Schmidt, Neckarsulm) containing about 84 % aluminium, 12-14 % silicon, the remainder being copper, nickel and magnesium.

The *crankshafts* as a rule are made from special steels. The finish of the surfaces depends on the type of bearings (plain bearings or roller bearings) and the bearing metal.

Vibration dampers are used nearly everywhere. They consist of disks, which are carried between friction surfaces. The vibration dampers are generally fitted on the end of the crankshaft opposite to that carrying the flywheel.

The bearings still give trouble everywhere on high-power engines; however, the nature of such difficulties has not always been reported. With regard to the overhauling intervals of engines fitted with roller bearings (for instance, *Maybach* engines) great improvements have been reported. Whereas a few years ago these bearings would cover only about 20 000 km. (12 400 miles) they now cover 80 000 km. (50 000 miles) and even over 100 000 km. (62 000 miles). These bearings are being improved all the time. For plain bearings, white metal cast on metal frames in the case of heavy loads, and lead-bronze are used, the latter being preferred in recent designs.

The lubricating oil is generally filtered through wowen metal or cloth fabrics; in Germany filters with superposed metallic disks are also used.

The lubricating oil is cooled as a rule in the case of engines with plain bearings (except for small powers). The *Maybach* engines equipped with roller bearings and ventilated crank case do not require any lubricating oil cooling radiator, which is a great advantage when the engine is carried on a bogie.

For checking the oil pressure easily, simple pressure gauges are sometimes used; however, as their indications may sometimes remain unobserved, preference is sometimes given to pressure gauges fitted with a contact which actuates an audible signal, or lights up an alarm lamp as soon as the oil is lacking. The diesel engine governor can also be made dependent on the oil pressure. (In the case of the Maybach engine, the governor cuts off the fuel supply, as soon as the oil pressure drops below a given figure).

As to how often the oil must be renewed there are great differences in this respect from one country to another. Germany and Hungary renew the oil as soon as 6 000 to 7 000 km. (3 730 to 4 350 miles) have been run; other countries only after as much as 30 000 km. (18 600 miles), and in a few countries it is renewed after even longer mileages. If large quantities of new oil are added frequently to make good the losses, it is, of course, possible to lengthen the interval

between oil renewals. This practice appears to be followed in several countries, which no doubt explains the big differences reported. Furthermore, some engines require much oil.

Regenerated oil is used in Germany and Austria with excellent results, but in *Czechoslovakia,* on the contrary, the experience with such oil appears to have been unsatisfactory. Regenerated oil is being used sucessfully in smaller engines or gearboxes.

The efficiency of the radiators without fans usually carried in the roof of the older type of railcars, depends on the direction of the wind and its relative force, and may sometimes fail, especially on steep gradients which can only be taken at low speeds.

In *Germany,* therefore, radiators with fans are carried below the floor on all high-power railcars, and also on most of the vehicles of smaller power; *Austria, Poland* and *Hungary* do likewise.

Czechoslovakia, on the contrary, prefers — most likely because of is simpler construction — cooling by natural ventilation. In the case of high-powers, coiled pipes have been fitted above the roof and nearly the whole length of it.

The temperature of the cooling water when entering the engine jacket varies for the bigger engines between 55 and 65° C. (131 and 149° F.) and for the smaller engines between 65 and 75° C. (149 and 167° F.).

Most of the latest designs of railcars are equipped with an arrangement for preheating the cooling water before starting up the diesel engines. An advantageous way of doing this is to pass steam from a separate generator through a flexible piping into the expansion chamber. At the same time the water is circulated by an electrically-driven centrifugal pump.

This arrangement has given better results than the direct introduction of steam into the cooling water. If the railcar is equipped with hot-water heating or hot-air heating, the hot-water being used to carry the heat, the engine cooling water can also be preheated by the heating plant of the coach.

Furthermore it is also possible, especially when running down long gradients, to send current from the main generator, in the case of railcars with electric drive, to heating resistances, in order to prevent the temperature of the cooling water becoming to low.

The average mileage run between two heavy repairs is :

—	—	Diesel engines. Km. (*miles*).	Carbuttor-fitted engines. Km. (*miles*).
Germany	Up to 300 H.P.	120 000 (*75 000*)	
	Over 300 H.P.	60 000 to 100 000 (*37 300 to 62 000*)	150 000 (*93 000*)
Austria	Up to 210 H.P.	200 000 (*124 000*)	120 000 (*75 000*) [Daimler only 60 000 (*37 500*)]
Hungary	Up to 120 H.P.	140 - 150 000 (*87 - 93 000*)	120 - 130 000 (*75 - 80 800*)
Poland	Up to 210 H.P.	100 - 120 000 (*62 - 75 000*)	...
Czeckoslovakia . .	Up to 210 H.P.	120 000 (*75 000*) (for rail motor cars running at v = 100 km.= *62 miles* an hour).	...

In addition to the general overhauls, intermediate repairs are given at varying intervals. The practice on the different railways in carrying out these repairs differs much. For instance, in Czechoslovakia three intermediate repairs are given after running 7 000, 20 000 and 40 000 m. (4 350, 12 400 and 24 800 miles) respectively.

Germany gives all its big engines an intermediate repair after 30 000 to 40 000 km. (18 600 to 24 800 miles) and its smaller engines every three months.

Poland gives an intermediate repair after running 20 000 km. (12 400 miles), and Jugoslavia every time after 10 000 km. *(6 200 miles)* have been covered.

Hungary has monthly, quarterly and half-yearly repairs.

Austria gives its railcars a light repair after running 30 000 km. (18 600 miles) and sends them to the repair shops for overhaul, after running 60 000 km. (37 200 miles).

These differences are partly due to the relative importance of the intermediate repair given.

The number of the *spare engines* in proportion to those required to cover the regular working depends principally on the mileage run and varies between 10 and 20 %.

* * *

III. — Installation of the power plant.

The location of the power plant has a great influence on the construction of the railcar.

(*a*) When there are bogies, the usual practice is to carry the power plant on the bogie frame. As a rule the engine and the transmission, or the generator are supported at 3 points on the bogie frame and are connected by a short shaft with elastic joints. The fastenings are usually rigid, although of late, rubber pads have been inserted. On the *Deutsche Reichsbahn*'s high-speed railcars, the diesel engine and the generator are carried on sub-frames, suspended from the bogie frame. The links of such a suspension are said to wear out very quickly. With the *Ringhoffer Tatra* engine a similar suspension is used, rubber pads being, however, inserted (see figs 15 and 16).

Further particulars in respect of the method of carrying the power plant on the bogies can be found in the report of Messrs. DUMAS and LEVY, pages 916 and 960.

A recent and interesting solution of this problem is that incorporated in the bogies for a high-speed railcar of the *Czechoslovak State Rys., Ringhoffer-Tatra* design (see chapter VI).

In proportion as the equipment becomes larger, the bogie wheel-base is also increased as shown by the above case. It is then very difficult to make the power plants sufficiently accessible. The reason for carrying the power plant on the bogie was primarily to protect the passenger compartments against vibration and noise.

Once this fear has been overcome by suitable means, for example, by rubber bearings, noise dampers, etc.) many good reasons can be advanced for not carrying the power plant on the bogie frame, especially as it is becoming more and more difficult and even impossible to do so with the continual increase in the size of the engines. The most powerful diesel engine so far carried on the bogie is undoubtedly the G 06 600-H.P. Maybach engine (see table II and fig. 1) used on the Reichsbahn's high-speed triplet. (For a detailed description see the *V.D.I.*, September 14th, 1935, p. 1113. With this installation various difficulties were already experienced, especially with regard to fitting the bogie brake gear.

A new method of building in the power plant was then developed, with the 560-H. P. plant carried on the transsoms of the body underframe, rubber pads being used extensively. (See *Organ für die Fortschritte des Eisenbahnwesens*, No. 17,

Fig. 15.

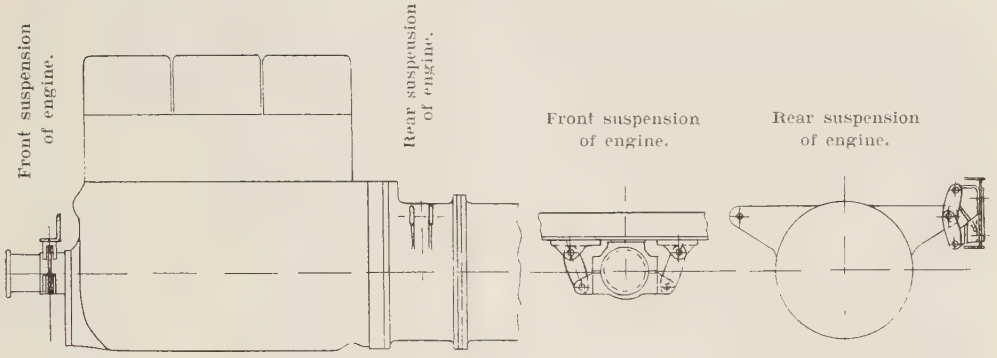
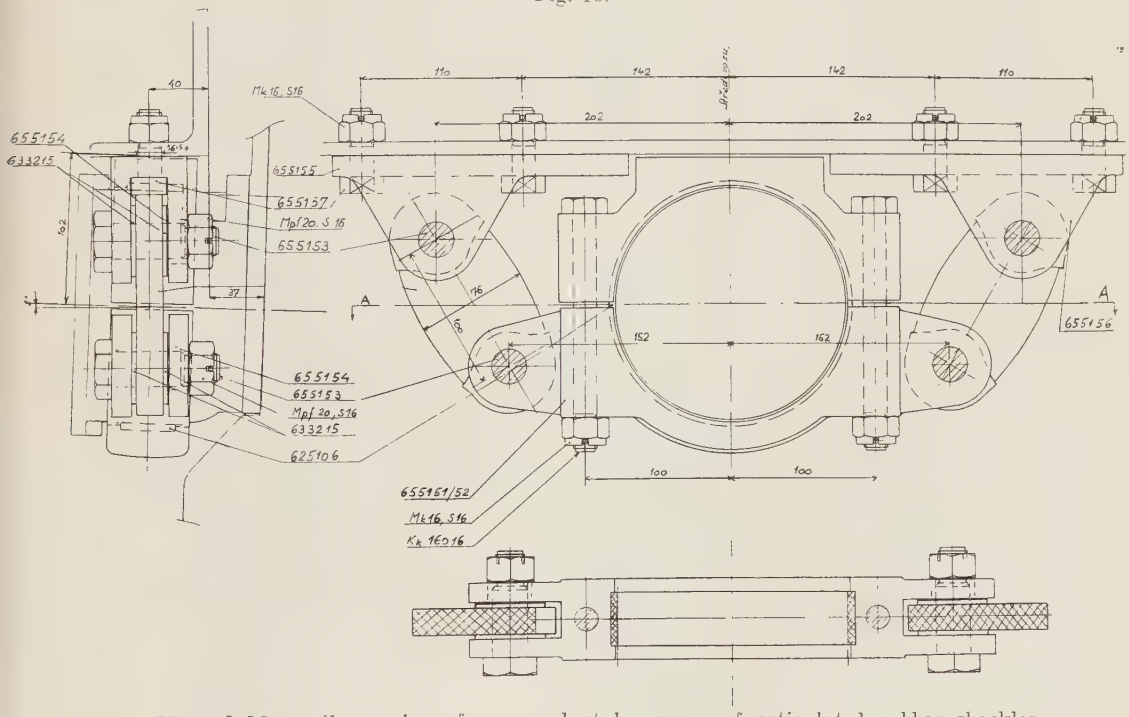


Fig. 16.



Figs. 15. and 16. — Suspension of power plant by means of articulated rubber shackles.

Sept. 1st, 1936). This arrangement has been found satisfactory on several trial railcars. With this construction the vibrations were no more noticeable in the passenger compartments than when the power plant is carried on the bogie.

The Reichsbahn has gone still farther in the case of the latest 4-unit high-speed

rail motor train now under construction, and which will be described in detail later on. The power plant, which is in this case accessible from all sides, is carried in the middle of the body of the motor unit which also includes the mail and luggage compartments. The 3 other units countain no mechanical plant apart from the electric driving motors on both end bogies.

(*b*) In railcars not carried on bogies, the whole power plant is carried on a sub-frame suspended underneath the carriage floor. The sub-frame itself is either suspended from the carriage underframe or is spring supported on the carriage axles. In the latter case, vibrations from the engines are efficaciously prevented from reaching the carriage body; but owing to the length of the sub-frame, this construction is, however, rather heavier. If the sub-frame is suspended from the underframe, the vibrations have to be damped out and the noises deadened by means of lightly loaded rubber packings.

The method of mounting the power plant on four-wheeled railcars so far followed in Germany is shown in figure 17.

Vertical motors nearly always project through the floor into the body, unless the engine is very small or the floor high enough. Owing to the increased fire risk, the practice of bringing the engine through the floor is undesirable. Moreover the space inside the car cannot be made as good use of. Makers have therefore endeavoured to build flatter and lower engines.

Keeping the power plant « under the floor » is now much facilitated by the development, in recent years, of horizontal engines of even considerable power. This fact is of great importance for four-wheeled railcars, because in this case the whole of the limited floor space, due to the necessarily short length of the cars, can be used for passenger transport purposes. For railcars of greater length too, the horizontal engines may also present great advantages. The total power can be easily divided between 2 engines in this case without any sacrifice of useful space. The eight-wheeled diesel-hydraulic observation railcar of the Reichsbahn (figs. 50 and 51) is a striking example of how the use of horizontal engines and the installation of the whole power plant under the floor have eliminated all cumbersome parts in the body.

Rubber pads are being inserted more and more extensively in new railcars. It is true that it is still too soon to express any formal opinion as to the effect of these devices on the behaviour of the engines. It may be admitted, however, that their use is advantageous.

In *Germany,* the railcars with very powerful engines carried on the carriage underframe through rubber pads have not yet been long enough in active service for any definite opinion to be given. The results, however, have been quite favourable so far. Further details will be found in the above mentioned article on the 560-H. P. railcars. Steel springs embedded in vulcanised rubber, and rubber vulcanised directly onto steel plate are also being used at present.

Rubber parts are protected against oil and other outside harmful influences by lining them.

If the vibrations are to be damped out properly, it is of primary importance that the vibration period of the springs does not synchronise with that of the engine.

Double-walled engine casings, insulated floors and partitions are used for deadening noise.

* * *

IV. — Power transmissions.

Table III shows the transmissions most used at present or being designed. Further details of each type of transmission as well as a description of the newest and not previously described types are given below.

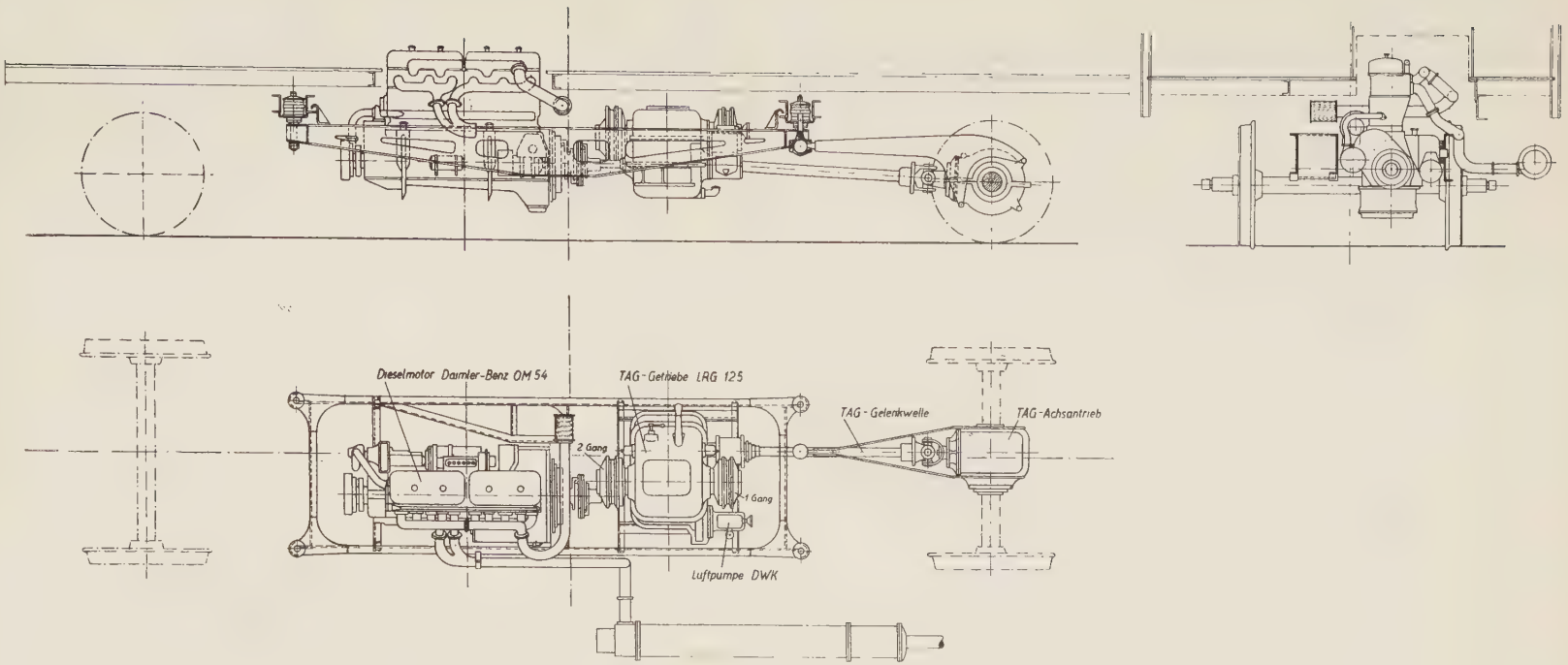


Fig. 17. - Installation of the internal-combustion power plant in 4-wheeled railcars.

Explanation of German terms :

Dieselmotor Daimler-Benz = Daimler-Benz diesel engine. — **T. A. G. Getriebe** = T. A. G. gearbox. — **Luftpumpe D. W. K.** = D. W. K. air pump. — **T. A. G. Gelenkwelle** = T. A. G. cardan shaft. — **T. A. G. Achsantrieb** = T. A. G. axle drive.

TABLE III.

Seq. No.	Builder, type of transmission : mech., hydr., electr.	Licensee if any. Remarks.	Number of units.	Maximum horse-power transmitted.	Maximum engine spe (r.p.m.)	
					driving shaft.	lay shaft.
1	2	3	4	5	6	7
	A. Mechanical transmissions.					
1	Fross-Büssing.	Austria.	3	60	1 000	1 000
2	Automobilfabrik Odense Gearbox : Zahnradf. Friedr.	Denmark.	2	80	2 200	...
3	Ganz.	JmR 150 and JaR 135 Hungary.	121	120	1 400	1 400
4	Skoda-M 130.1	Czechoslovakia.	...	120	1 600	231/1 60
5	Tatra — M 120.4, M 130.2.	Czechoslovakia. Planet gear.	...	120	1 300	256/1 30
6	Mylius.	Poland & other Countries	33	100/150	1 350	645
7	Voith/Maurer.	»	22	100/150	1 350	...
8	Triebwagenbau A.G. Kiel L.R.G. 125.	Germany.	35	150	1 500	1 015
9	»	Rumania.	20	...	...	...
10	Deutsche Getriebe GmbH. Mylius-CV2	»	50	150	1 500	1 500
11	Skandia design.	Austria.	6 + 2	150	1 000	1 000
12	Marchalowski design.	»	4 + 2	150	1 000	100
13	Ganz-Jendrassik.	Rumania.	49	150	...	...

ver transmissions.

Speed gear. Type.	Number of speeds with mech. and hydraulic transmiss.	Total weight of transmission (metr. t.).	Type of reverse gear.	Denomination of control system in the case of electric transmissions.	System of distant control : electric, pneumatic, multiple control, etc.
9	10	11	12	13	14
Gearbox (sliding double change speed wheels).	3	...	Separate reverse gear.	...	Mechan. (cables).
Disk coupling.	4	0.2	Bevel wheel reverse gear.	...	Mechanical.
»	4	0.6	Conical gear wheels.	...	Air pressure.
Special gearing.	4	0.44	»	...	Mechanical.
Speed changed by braking and blocking the corresponding driving wheel.	4	0.41	Reversible engine.	...	»
Claw coupling synchronised by bevel gear.	4	with reverse gear 0.8	Bevel wheel reverse gear.	...	Air pressure.
Voith/Maurer.	2	0.47	»	...	»
Multiple-disc clutch (pneumatic control).	4	incl. axle drive. 1.0	Reverse gear housed in gearbox.	...	»
...	...	...	...	..	»
Claw coupling synchronised by bevel gear.	4	0.315	Bevel wheel reverse gear.	...	»
Gearbox (sliding double change speed wheels).	4	...	Reverse gear in gearbox.	...	Mechan. (cables).
Pneumatically operated clutch.	4	...	Separate reverse gear.	...	Air-pressure.
...	...	0.75	Ganz.	...	»

TABLE

Seq. No.	Builder, type of transmission : mech., hydr., electr.	Licensee if any. Remarks.	Number of units.	Maximum horse-power transmitted.	Maximum engine sp (r.p.m.)	
					driving shaft.	lay shaf
1	2	3	4	5	6	7
13a	Ganz & Co.	Bulgaria.	1	150	150	150
13b	A/S Strommens Værksted.	Norway.	14	150	1 600	1 60
13c	N.S.B.	Norway.	16	150	1 600	1 60
13d	N.S.B.	Norway.	6	200	1 600	2 01
14	Mylius.	»	50	200	...	...
15	Ganz.	Poland.	3	220	1 250	575
16	»	JmR 150 and JaR 135 Hungary.	8	270	1 250	1 25
17	»	Egypt.	...	275	...	1 45 R.P.M
18	Triebwagenbau-A.G., Kiel.	Germany. Experimental design.	1	300	...	...
19	Deutsche Getriebe GmbH-Mylius.	» Experimental design.	1	300	...	...
20	Winterthur.	Switzerland.	2	...	...	...
	B. Electro-mechanical transmission.					
21	Sousedik-Tatra M 290.	Czechoslovakia.	...	165	1 230	...

ntinued).

Speed gear.		Number of speeds with mech. and hydraulic transmiss.	Total weight of transmission (metr. t.).	Type of reverse gear.	Denomination of control system in the case of electric transmissions.	System of distant control : electric, pneumatic, multiple control, etc.
n- of s.	Type.					
	9	10	11	12	13	14
	Oil-immersed disk clutch for each speed.	4	0.65	Bevel gear wheels.	...	Pneumatic.
	Claw coupling.	4	0.45	Bevel gear wheels.	...	Pneumatic.
	Synchr. claw coupling.	4	0.205	»	...	»
	»	8	0.435	»	...	»
	...	4	0.35	Mylius.	...	»
	Ganz.	5	with reverse gear. 1.75	Reverse gear housed in gearbox.	...	»
	Disk coupling.	5	1.5	Spur gear wheels.	...	»
	Steel disks.	5	...	Reverse gear keyed to multiple dry disk coupling built in flywheel. Reverse gear shaft is driven either directly or indirectly from the driving shaft.		Pneumatically-operated from both driver's compts.
	Multiple disk clutch, pneumatic.-operated.	4	...	Reverse gear housed in gearbox.	...	»
	Claw coupling synchronised by bevel gear.	5	...	Reverse gear housed in gearbox.	...	»
	Oil-pressure operated coupling.	5	3.6	Pneumatically-operated clutch shaft.	...	Electropneumatic.
	(See special description.)	...	...	Pneumatically-operated bevel gear wheels.	Mechan.-electr. Sousedik-design.	»

TABLE

Seq. No.	Builder, type of transmission : mech., hydr., electr.	Licensee if any. Remarks.	Number of units.	Maximum engine power.		Fluid transmissio	
				H.P.	R.p.m.	Driving shaft.	Lay shaf
1	2	3	4	5		6	7
	C. Hydraulic transmissions.						
1	Automobilfabrik Odense. Voith-Heidenheim.	Jugoslavia.	1	80	2 200	2 200	..
2	Voith—turbodrive.	Austria.	21	100	...	3 000	3 00
3	Voith—high-ratio double turbo-drive.	Germany.	2	180	1 500	3 040	2 93
4	Voith—turbodrive.	»	3	200	1 500	1 500	a lit unde 1 50
5	Voith/T.A.G.	»	2	280	...	1 962	1 84
6	Voith—high-ratio double turbo-drive.	»	30	360	900	2 860	2 790 (
7	Voith/Maybach.	»	2	410	1400	2 890	2 575 (
8	Voith/T.A.G.	»	2	420	1400	2 260	2 20
9	Voith/T.A.G. high-ratio.	»	4	600	1400	1 862	...

(*) at = 100 km./h. — (**) at 90 km./h.

ontinued).

Speed gear.		Number of speeds with mechan. and hydr. drives.	Weight of transmission (total) (metr. t.).	Type of reverse gear.	Denomination of control system in the case of electric transmissions.	System of distant control : electr., pneumatic, multiple-unit control, etc.
m- of eds.	Type.					
9		10	11	12	13	14
	...	2 W/K	0.2	Bevel gear.	...	Air pressure.
	...	...	...	Separate reverse gear.	...	Electro-pneumatic.
	...	3 W/K1 + K2	0.7	»	...	»
	...	2 W/K	0.6	»	...	Air pressure.
	...	2	...	»	...	Electro-pneumatic.
	...	3 W/K1 + K2	1.5	»	...	»
	...	3	4.8	»	...	Multiple-unit electro-pneumatic control.
	...	2	...	»	...	Single electro-pneumatic control.
	...	2 W Speed 0-110 km./h. Reaches 110-160 km./h.	Including reverse gear and axle drive. 7.375	Reverse gear keyed to fluid gearbox.	...	Electro-pneumatic.

TABLE

Seq. No.	Builder, type of transmission : mech., hydr., electr.	Licensee if any. Remarks.	Number of units.	Maximum engine power.		Fluid transmissio	
				H.P.	R.p.m.	Driving shaft.	Lay shaf
1	2	3	4	5		6	7
	D. Electric transmissions.					Maximum number of r.p.m.	
1	Siemens-Schuckert-Werke.	Rumania.	14	Generator 45 *KW* Motor 40 H.P.		950 850	...
2	»	»	9	Generator 65 *KW* Motor 40 H.P.		950 850	...
3	»	Germany.	2	130 H.P.		1 700	...
4	Brown, Boveri & Co.	»	10	150 »		1 500	...
5	»	Austria.	2	200 »		1 000	...
6	Gebus.	Austria and Bulgaria.	11+1	210 »		1 500	...
7	Brown, Boveri & Co.	Czechoslovakia.	...	210 »		1'300	...
8	Gebus.	Poland.	5	240 »		800/1 350	...
9	Titan, Copenhagen Asea, Västeras (Sweden).	Denmark.	22	250 »		...	...
10	Thomas B. Thrige, Odense.	Jugoslavia.	3	280 »		1 100	...
11	Ö.S.S.W.	Austria.	20	300 »		1 350	...
12	A.E.G., S.S.W., B.B.C.	Germany.	10	410 »		1 400	...
13	C.K.D., M. 275.0.	Czechoslovakia.	»	450 »		1 150	...
14	A.E.G., S.S.W.	Germany.	4	600 »		1 400	...
15	B.B.C.	(under construction).	3	1 300 »		700	...

ontinued).

Speed gear.		Number of speeds with mechan. and hydr. drives.	Weight of transmission (total) (metr. t.).	Type of reverse gear.	Denomination of control system in the case of electric transmissions.	System of distant control : electr., pneumatic, multiple-unit control, etc.
um-er of eeds.	Type.					
8	9	10	11	12	13	14
...	...	...	...	...	...	Electric.
..	...	...	...	...	...	»
..	...	...	...	By reversing field of traction motors.	Gebus system.	»
..	...	...	2.6	»	B.B.C. system.	»
..	...	...	...	Reversing armature current or field of traction motors.	...	»
..	...	...	...	»	...	»
..	...	...	...	»	Automatic regulation through excitation of main generator (with power relay).	»
..	...	...	3.7	»	...	»
..	...	...	...	...	...	»
..	...	...	...	...	R.Z.M.	»
..	...	...	...	Reversing armature current or field of traction motors.	...	»
..	...	...	Total of electrical gear. 7.8	»	R.Z.M. 5 speed steps.	Electr. dist. contr.
..	...	...	...	»	Automatic torque regulation by excitation of main generator.	...
..	...	...	10.3	»	R.Z.M.	Electr. dist. contr.
..	...	...	...	»	B.B.C. Servo-field regulation.	»

Railcars.

Description.	Total horse-power.	Supplier of		
		Engine.	Transmission.	Vehicle.
			A. 4-wheeled railcars.	
Diesel-mechanical.	135	Daimler.	T.A.G.	Linke-Hofmann
»	150	M.A.N.	Mylius.	M.A.N.
»	150	M.A.N.	»	M.A.N.
»	150	M.A.N.	9 Mylius.	Bautzen.
»	150	M.A.N.	1 Stöckicht.	
»	150	M.A.N.	Mylius.	Rathgeber.
»	150	»	»	Esslingen.
»	150	»	»	Nürnberg.
				Rathgeber.
»	150	»	»	Esslingen.
				Bautzen.
Diesel-hydraulic.	180	D.W.K.	A.E.G (new).	Linke-Hofmann
»	210	M.A.N.	Voith.	M.A.N.
			B. 8-wheeled railcars.	
Diesel-hydraulic (narrow gauge).	180	Vomag.	Voith.	Bautzen.
Diesel-mechanical.	210	Maybach.	Maybach.	Görlitz.
				Dessau.
				Dessau.
»	210	»	»	Talbot.
				Lindner.
				Danzig.
Diesel-hydraulic.	225	»	Voith.	Westwaggon.
»	210/280	M.A.N.	T.A.G.-Voith.	Talbot.
Diesel-electric.	300	Daimler.	A.E.G.	Linke-Hofmann
»	300	M.W.M.	A.E.G.	Linke-Hofmann
Diesel-mechanical.	280	M.A.N.	T.A.G.	Dessau.
	300	Daimler.	Mylius.	
Doble steam.	2 × 150	3 Borsig. 2 Henschel.		Wegmann.
»	»	Borsig. Henschel.		Wismar.
Diesel-hydraulic.	2 × 180	D.W.K.	Voith.	Fuchs.

ermany.

Number		Number of passengers		Weight in working order (empty).	Luggage.	Total weight without standing passengers.	Weight per metre of vehicle body length inside buffers. (Metr. t.).	Remarks. (Without buffers).
ordered.	supplied up to 31-12-36.	seated.	standing.					
9		45	25	15.5	...	19.0	1.7	
4	9	44		16.2	...	19.7	1.7	
2		44		16.0	...	19.5	»	
10	...	»		16.2	...	19.7	1.7	
20	...	»	25	»	...	»	...	
30	...	»		»	...	»	...	
1	1	46	25	15.7	...	19.2	1.7	
3	3	44	»	16.8	...	20.3	1.81	
4	...	...	...	...	...	...	...	
19	19	61	39	30.7	...	...	...	
28	28	63	43	33.5	...	...	...	
20	...	...	...	...	...	...	...	For branch lines.
2	...	...	...	...	...	...	...	
10	6	69	44	41.0	...	...	...	
5	...	66	44	44.7	...	...	...	
2	...	...	...	...	...	...	...	Trial transmission.
5	2	60	...	43 — 44	...	...	...	
4	...	60	...	...	...	...	...	
1	1	60	44	43	...	...	...	1 observation railcar.

Description.	Total horse-power.	Supplier of		
		Engine.	Transmission.	Vehicle.
Diesel-hydraulic.	2 × 180	D.W.K.	Voith.	Wumag.
»	360	M.A.N.	Voith.	Düsseldorf Ürdingen Dessau.
	360	Deutz.		Westwaggon.
Diesel-electric.	410 to 450	Maybach 65 M.A.N. 28 Daimler 3	S.S.W. A.E.G. B.B.C.	Düsseldorf, Wismar Talbot, Westwaggon
Diesel-hydraulic.	410	Maybach.	Voith.	Westwaggon.
»	420 (1)	M.A.N.	T.A.G.-Voith.	»
»	420 (2)	M.A.N.		»
	450	Deutz.		Westwaggon.
Diesel-electric (3).	560	M.A.N.	B.B.C.	M.A.N.
Diesel-hydraulic (3).	2 × 275	Daimler. D.W. Kiel. M.A.N. Deutz.	Voith.	Wumag.
			C. **Multiple-unit railcars.**	
Fast diesel-electr. twin railcar (Flying Hamb.).	2 × 410	Maybach.	S.S.W.	Görlitz.
Diesel-electr. twin railcar for Ruhr District.	2 × 410	»	»	»
Fast diesel-electr. triple railcar (Leipzig).	2 × 600	»	T.A.G. Voith.	Linke-Hofmann
Fast diesel-electr. triple railcar (Leipzig).	»	»	A.E.G.	»
Kruckenberg diesel-hydr. triple railcar.	2 × 600	»	Voith.	Westwaggon.
Diesel-electr. triplets for main lines.	2 × 450	Daimler.	B.B.C.	»
Fast diesel-electr. triplet (Cologne).	2 × 600	Maybach.	A.E.G. S.S.W.	Linke-Hofmann
Diesel-electr. triplet for Ruhr District.	2 × 410 2 × 450	3 Maybach. 2 Daimler.	Voith.	Westwaggon.
Diesel-electr. 4-unit train.	1 300 (4)	M.A.N.	B.B.C.	M.A.N. Nürnberg.

Number		Number of passengers		Weight in working order (empty).	Luggage.	Total weight without standing passengers.	Weight per metre of vehicle body length inside buffers. (Metr. t.).	Remarks. (Without buffers).
ordered.	supplied up to 31-12-36.	seated.	standing.					
3	...							
30	...	65						
3	...							
36	36	61	45	45 b				
60	60			47 t				
2	1	61	45	42.0				
2	...	59	45	46.0	...	...	...	(1) Engine with 2 crank shafts.
4	...	...	...	...	...	...	...	(2) Engine with single crank shaft.
4	...							
4	4	56	46	49				
6	...	...	...	...	...	...	...	(3) With horizontal engine.
13	13	77	...	91.3 b 92.0				
8	...							
2	2	140	...	130				
2	2	»	...	120.1				
1	...							
2	...							
6	...							
5	...							
2 + 1 power-vehicle.	...	...	...	...	...	...	...	(4) Plus one 150-H.P. auxiliary engine.

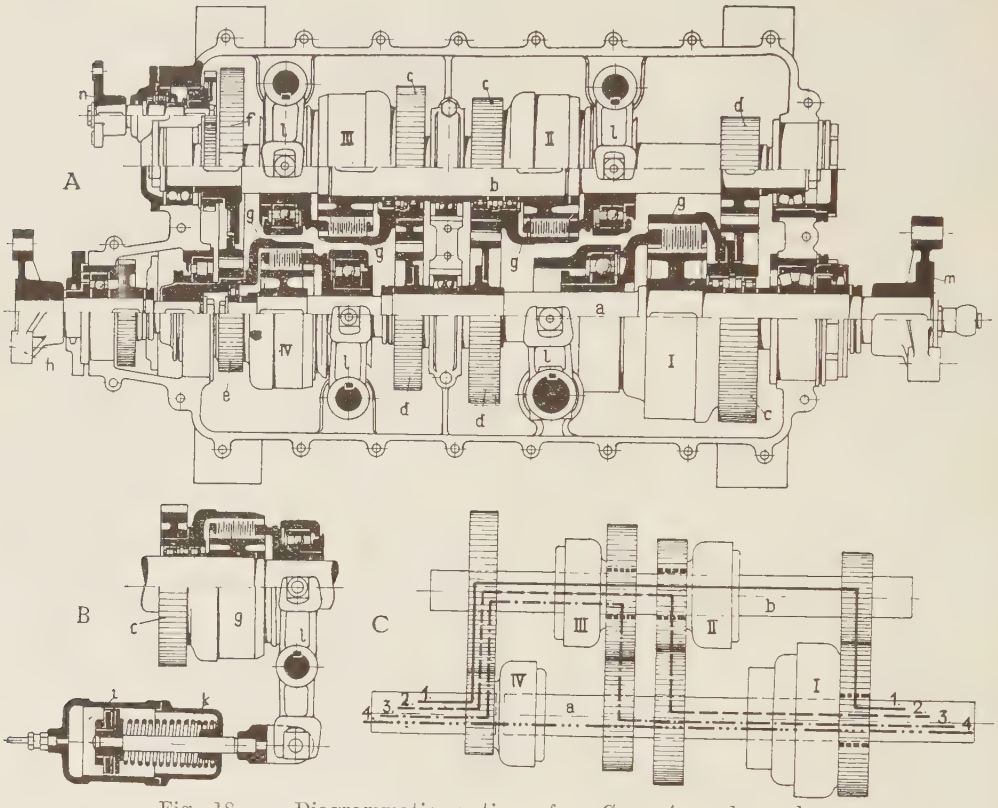


Fig. 18. — Diagrammatic section of a *Ganz* 4-speed gearbox.

A. Horizontal section of gearbox.
B. Diagram of speed gear control by compressed air servo-motor.
C. Diagram of the four speed gears.

The Roman numerals indicate the gears in mesh at the corresponding speeds, and the Arabic numerals the path followed by the power transmission for each speed.

a. Driving shaft.
b. Lay shaft.
c. Loose gear wheels.
d. Gear wheels keyed on shaft.
e.f. Spur gear driving lay shaft.
g. Steel disk clutch.
h. Coupling on engine side.
i. Servo-motor.
k. Counter spring of servo-motor
l. Control lever of speed gear.
m. Coupling on axle side.

Mechanical and hydraulic drives are most suitable for railcars up to 200 H. P., owing to their lightness, simplicity, and reliability (Some of these drives are, however, rather complicated).

Hydraulic drives have also been tried for high powers (300, 400 and 600 H. P.). Railcars equipped with them, however, have not been long enough in service to express any definite opinion. In Germany the experience with hydraulic drive not only on medium-powered cars but also with the 600-H. P. engines of the high-speed triplets has been very satis-

factory. In this design, provision was made subsequently for emptying the liquid from the speed gears quickly when stopping the diesel engines, in order that, for example, the engine shall not continue to drive through the transmission gear in case of damage.

When the power exceeds 200 H. P., the electric transmission is still most used at present on account of its working reliability and its suitability for distant control.

a) Purely mechanical transmissions (gear wheels).

The transmissions (gear wheels) are generally used for powers under 200 H. P. A few railways have used such gear up to 300 H. P., for example, in Hungary for 220/275 H. P., and in Switzerland for 300 H. P. In Germany trials will also be made shortly with a similar transmission for 300 H. P. The test made with these transmissions have so far been satisfactory, but it is too early to arrive at any final conclusion. A private German railway has fitted several railcars with the *Ardelt* drive, which can transmit up to 150 H. P., and which is worth mentioning, as it works without interruption of the torque transmission, the change-over being by means of gears constantly in mesh.

Diagram of separate gears.

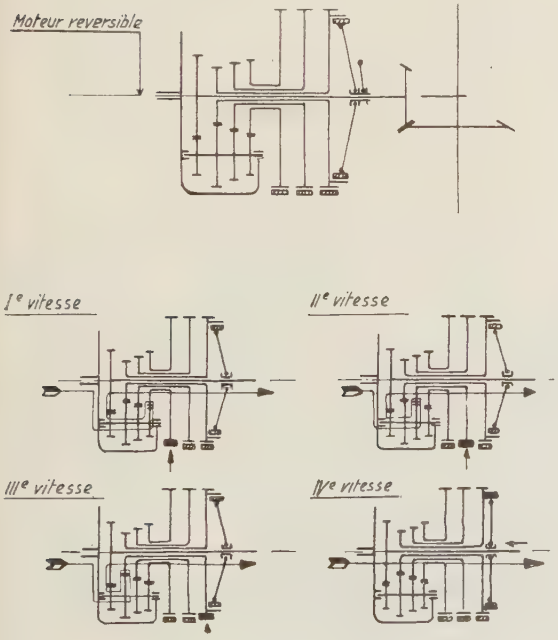


Fig. 19. — *Tatra* planet gearbox. (Railcar M 130-2).

Note. — I^e (II^e...) vitesse = 1st (2nd...) speed.

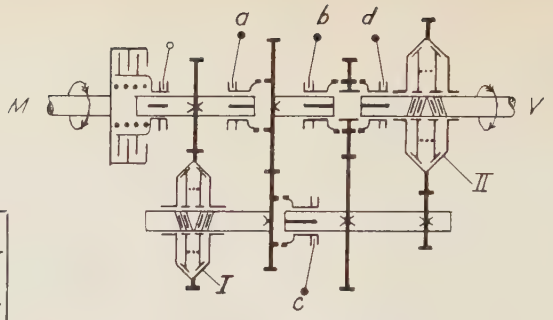
The number of speeds is generally 4, and for high-speed railcars, 5; in one particular case it is even 8 (Norway). In most cases the speed is changed by preselecting the gears which are always in mesh. In place of the claw couplings formerly preferred, friction couplings are more and more used. An an example figure 18 shows a Ganz four-speed gear box.

Planet (epicyclic) gear so far have only been speed used by the *Czechoslovak Rys.*, as far as the railways covered by this report are concerned. (*Tatra* system, see fig. 19 — diagram and description). The change of speed is generally obtained by stopping or disengaging the central toothed wheels. Although the use of a bevel *reversing gear*, unnecessary in this case if a reversible engine is provided, this epicyclic gear seems rather complicated. It contains several concentric shafts; the bearings do not appear to be very accessible.

A very interesting design is that shown by figures 20 and 21, used by the *Norwegian State Rys.*, because it gives a double number of speeds (8) by comparatively simple means without requiring much more room. A constructional feature is the 2 automatic friction couplings, the working of which is clearly shown in the diagram figure 20. The ratio is reduced as the inner shaft, fitted with a reverse thread, advances.

Speed. No.	Coupling claw.				Free wheel.	
	a →	b →	c ←	d ←	I.	II
N	×					
1		×			×	×
2			×		×	×
3	×	×				×
4	×		×			×
5		×		×	×	
6			×	×	×	
7	×	×		×		
8	×		×	×		
N	×			×		

< = engagement.



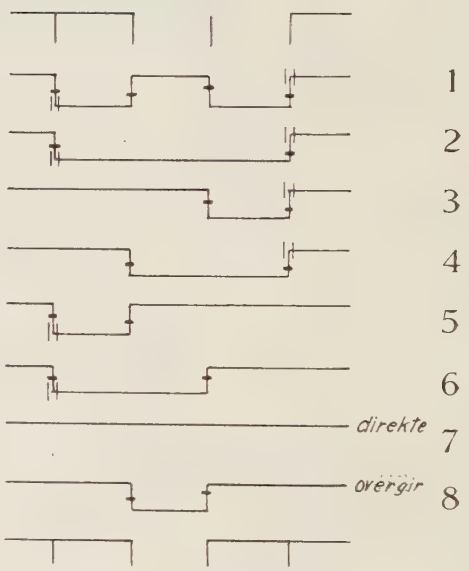


Fig. 20. — 8-speed gearbox of the *Norwegian State Railways.*

Translation of Nowegian terms : Direkte = direct drive. — Overgir = gear drive.

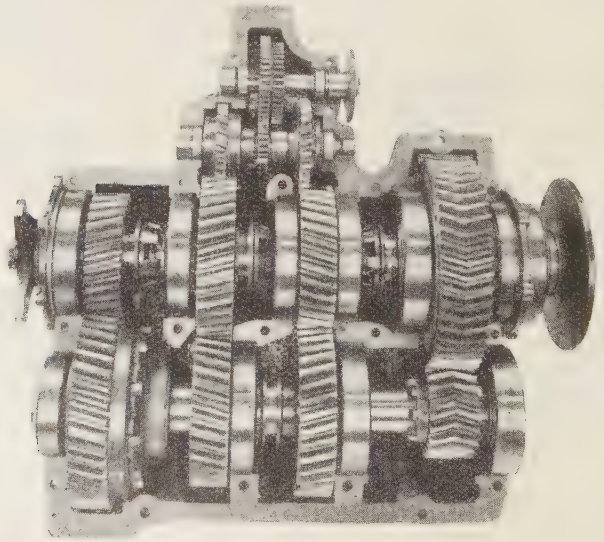


Fig. 21. — 8-speed gearbox of the *Norwegian State Railways.*

b) **Hydraulic transmissions.**

In general hydraulic transmissions find favour because of their more simple constructional features.

The *Voith* system of hydraulic transmission is used in the following countries : *Germany, Austria, Poland, Jugoslavia.* For a detailed description of same please see the *Monthly Bulletin* of the Railway Congress, August 1935, p. 952). The results so far are satisfactory. In Czechoslovakia trials are being made with the Lysholm-Smith systems (*Bulletin of the Railways Congress,* 1935, p. 953) but no details of the results obtained have been supplied.

It may be said that since the previous report was published, great progress has been made as regards room taken up as in the way of possible applications of the hydraulic drive.

In Germany, Voith-T. A. G. hydraulic transmissions have been provided on the triple-unit high-speed 2×600-h.p. rakes. Transmission of the considerable power, 600 h. p., from one engine has been obtained in this case by the *high number of revolutions of the driving shaft,* driven from the diesel engine, without any increase in the outside dimensions of the hydraulic drive being required over that necessary for the 400-h.p. gears. The fluid transmission gear consists of 2 torque converters working separately for different speeds [one for a speed of 0 to 110 km. (68.3 miles) an hour, and the other for 110 to 160 km. (68.3 to 100 miles) an hour]. The purely mechanical reverse gear is connected directly to the fluid transmission (see fig. 22). From this reverse box a cardan shaft runs to each of the driven axles (front and rear). The whole motive plant consisting of the diesel engine with supercharger, hydraulic transmission and reverse gear, as well as the 2 axle drives, could still be fitted inside the bogie frame.

In this bogie *both axles* are thus driven

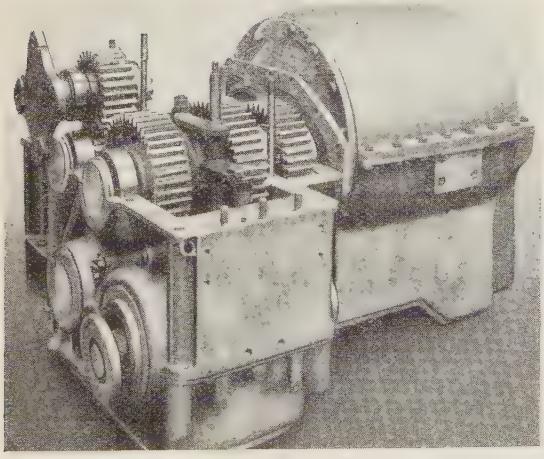


Fig. 22. — *T.A.G.-Voith* 600-h.p. gearbox with reverse gear.

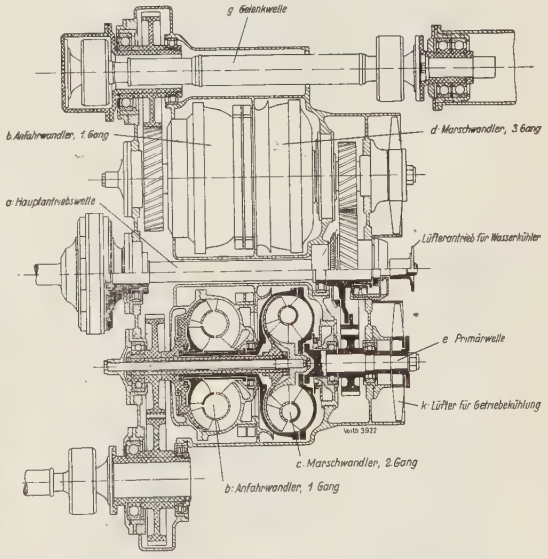


Fig. 23. — Example of a double 3-speed turbo-gearbox.

Explanation of German terms :

Gelenkwelle = cardan shaft. — Anfahrwandler, 1. Gang ... = starting torque converter for working 1st speed. — Luftanbrieb fur Wasserkühler = pneumatic drive of water cooler. — Primärwelle = main shaft. — Lufter für Gebriebekühlung = Speed-gear cooling fan.

by a single power unit. If the wheels of the two axles should not be exactly the same diameter, some torsional movements and additional stresses might be set up through the cardan shafts. As a trial, therefore, one of these high-speed railcars was fitted with an elastic coupling on one of the cardan shafts, arranged to slip when a given torque limit is reached. The other high-speed railcar was not fitted with this safety coupling, and so far no difference at all has been noticed in the running of the two vehicles.

The question of driving both axles from a single motive plant has meanwhile been solved more elegantly by Messrs. VOITH, by means of their so-called double turbo-transmission (see figures 23, 24 and 25).

There are, at each end of the central driving shaft 2 identical sets, each with one fluid starting gear and one torque converter for the normal running speed. A cardan shaft is driving the front axle actuated by the secondary shaft of set No. 1, and set No. 2 has the same arrangement for driving the rear axle. Both driving shafts are therefore inter-dependent, being only coupled through the fluid transmission and not rigidly. The power transmission ratio between set 1 and cardan shaft 1 on the one side, and between system 2 and cardan shaft 2 on the other side differs widely. Therefore, if when starting both torque converters are filled, and as soon as a certain speed is reached, only convertor 1, and at maximum speed only the convertor 2 is kept working, a total of 3 speed steps is obtained, with a very good efficiency curve. With the second and third speeds, only one axle is being driven, which is possible owing to the low torque, without any danger of the driving wheels slipping.

This design is mentioned under the numbers 3 and 6, table III, in connection with transmissions. It is too early to give a definite judgment on the ruggedness and resistance to wear of such apparatus.

In *Austria* the hydraulic transmissions (*Voith* system) which have been used for some time have given such good results that the *Austrian Federal Rys.* have

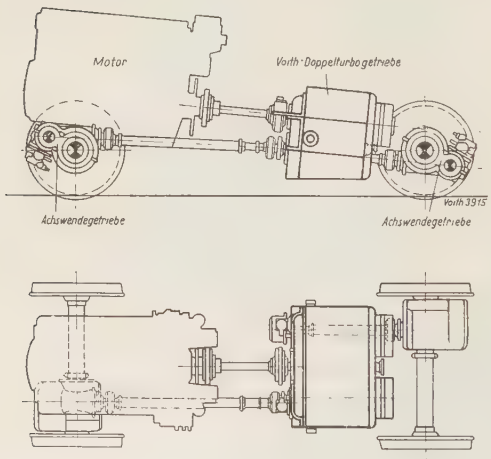


Fig. 24. — Motor bogie with *Voith-Maybach* transmission. General arrangement on bogie. Each axle has a separate hydraulic drive.

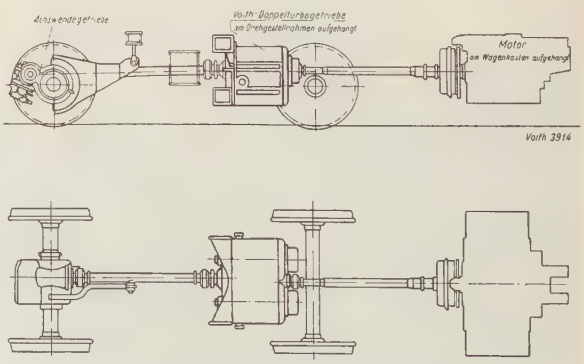


Fig. 25. — Bogie without engine, with double turbo-gearbox driving one axle.

Explanation of German terms :

Achswendegetriebe = Axle reverse gear. — Voith Doppelt-Getriebe (am Drehgestellrahmen aufgehängt) = Voith double fluid gearbox suspended on the coach underframe. — Motor am Wagenkasten aufgehangt = engine suspended on railcar body.

Fig. 26*a*. — Vertical section.

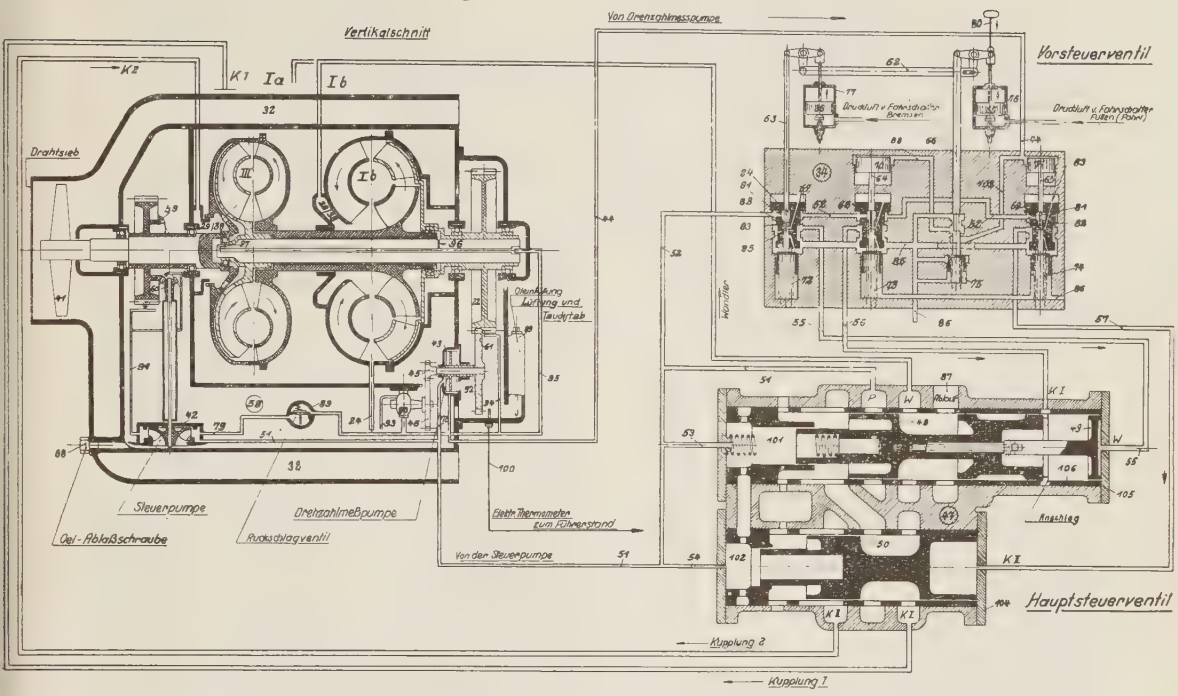
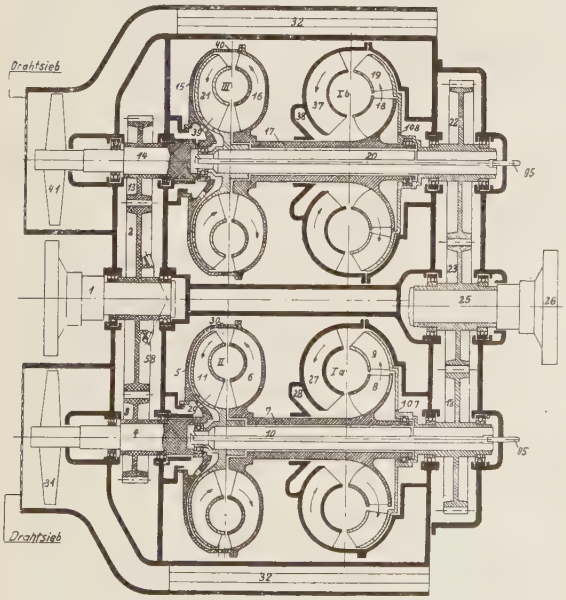


Fig. 26*b*. — Horizontal section.



Figs. 26*a* and *b*. — Diagrammatic sections of double turbo-transmission, with speed gear.

Explanation of German terms :

Drahtsieb = Wire gauze sieve. — Oel-Ablasschraube = Oil draining screw. — Rückschschlagventil = check valve. — Steuerpumpe = fluid speed gear pump. — Drehzahlmesspumpe = r. p. m. indicating pump. — Zum Führerstand = to driver's stand. — Von der Steuerpumpe = from the fluid speed gear pump. — Kupplung = Coupling. — Anschlag = stop block. — Druckluft vom Fahrschalter = Compressed air from control handle. — Bremsen = brakes. — Füllen (Fahrt) = filling (running). — Vorsteuerventil = speed preselecting valve. — Hauptsteurventil = Main speed gear valve.

now installed these transmission (torque converters and fluid couplings) on all new railcars (in so far as they are driven by petrol engines).

The fluid used is oil of low viscosity.

For *(a)* and *(b)* :

For the mechanical transmission of power *between the gearbox and the driving axle,* the following cases must be noted :

1. The reverse gear is one solid unit with the speed gearbox, or is fixed on it;

2. The reverse gear forms part of the axle drive;

3. The reverse gear is coupled directly to the engine;

4. By using a reversible engine, the reverse gear is quite unnecessary.

Furthermore, the design is still dependent on whether the jack shaft is fitted :

(a) either at right angles to the driving axle, or

(b) parallel to it.

In most cases the arrangment 2*a* is used. In this case a cardan shaft driving a bevel wheel is used to transmit the power. This wheel drives two other bevel wheels, which can be coupled as desired to the driving shaft (or a secondary or lay shaft parallel thereto).

The T.A.G. transmission works in accordance with the arrangement 1*a* and the *Mylius* transmission according to 2*a*.

Maybach uses an unusual arrangement. The reverse gear drives a jack shaft which in turn drives the axles by means of connecting rods. The Maybach original transmissions, built for 150 to 175 H.P. and mentioned in the *Bulletin of the Railway Congress,* 1935, p. 924, has been used more recently to transmit 210 H. P., in conjunction with a simple fluid coupling added solely in order to reduce shocks when changing gear. Maybach transmissions are giving satisfaction ; originally, however, the fluid couplings gave some trouble mainly due to lack of tightness.

For transmitting the power to the driving axles, the arrangement described in cases 1*a* and 2*a* is generally resorted to in the case of fluid couplings.

In the other countries, the arrangements described above are used.

The design of the *control devices* depends upon whether *one* or *two* power plants are used in *one and the same* vehicle, or a number of power units in several vehicles.

Purely mechanical control can only be used in the more simple cases; in more complicated cases, either compressed air or oil under pressure, or electric current actuating electro-magnets (in the case of clutches, for example) or electric servo-motors, are used. Furthermore, various combinations of these methods are used (mechanical, electric, electro-pneumatic, etc.). Electro-pneumatic control is much favoured and is used extensively, as powerful effects can be obtained with relatively weak currents.

The control of the different speeds in the hydraulic transmission, i.e. selection of the desired torque converter to be used, is obtained by filling or emptying the devices in question by means of valves, which operations in turn are controlled by various methods (rods, cables, compressed air, compressed oil, electro-magnets). For reversing, electro-pneumatic control is preferred. As soon as a number of apparatus have to be operated from a distance, which can be done without any difficulty (see for instance the triple high-speed diesel-hydraulic rake of the Reichsbahn) it is advisable to enable the driver to make sure that the different operations have been fully completed, this being shown by pilot lamps in the driver's cab, so that no conflicting movements can be effected at the same time.

c) Electric transmissions.

In *Germany* the following systems have been used :

Gebus, Lemp, Brown-Bovery Co. (B.B.

C.) with torque limiter, B.B.C. with servo-governor, A.E.G., R.Z.M.

The last mentioned system, tried and proved in many applications, is very simple and reliable. In Germany it has been adopted as standard. These different electrical transmissions have already been described in the *Bulletin of the Railway Congress*, August 1935, pages 945 to 951.

In *Austria*, the Ward-Leonard, Austrian S.S.W. and Gebus systems have been tried. The last mentioned has been used in preference. *Poland* and *Bulgaria* also use the Gebus system.

Czechoslovakia after making trials with various systems of electric connections expects much from the *very remarkable* Sousedik electro-mechanical transmission. In this case the stator as well as the rotor of the main generator revolve. The generator forms a kind of electric coupling, the slip of which decreases in proportion as the vehicle speed increases. When approaching synchronism an electro-magnetic clutch operates and the diesel finally drives the axles direct, as shown by figure 27.

The stator of the generator has the same number of revolutions as the diesel engine. Its rotor is coupled to the driving axles by means of bevel gear, so that its angular speed is directly proportional to the vehicle speed.

The cardan shaft connected to the driving axle is acted upon, besides by the turning moment of the generator stator, by an electric motor fed from the generator. When starting (which means a great slip) the turning moment of the generator rotor like that of the electric motor is considerable, and consequently also the starting effort on the driving axle falls off as the vehicle speed increases (reduced slip). Finally at about 95 % of the synchronous speed the diesel is coupled directly to the cardan shaft (and to the driving axle) under the action of the electromagnetic coupling, so that all transmission losses are eliminated. This system was found satisfactory with a 330-h.p. diesel engine. The electrical equipment should only weigh about 1/3rd of the ordinary electric transmission, because the greater part of the

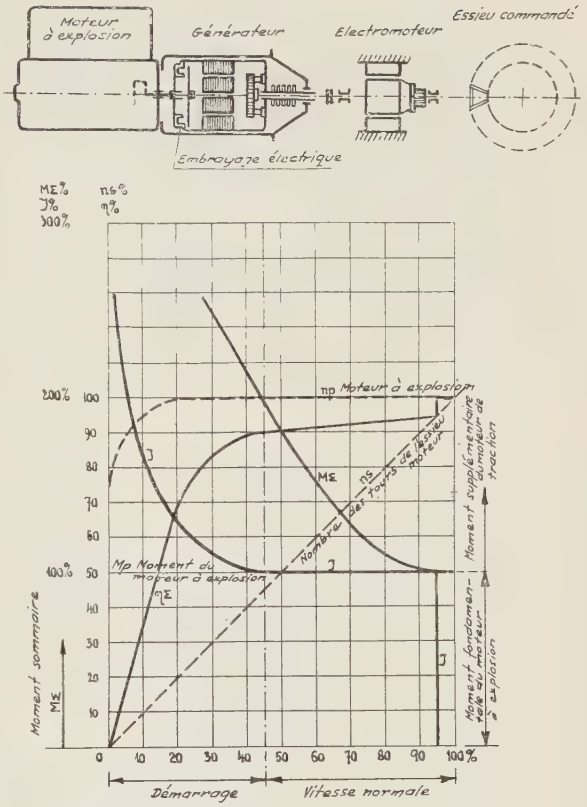


Fig. 27. — *Souzedik* type electro-mechanical transmission.

Explanation of French terms :

Moteur à explosion = petrol engine. — Générateur = generator. — Electro-moteur = electric motor. — Essieu commandé = driven axle. — Embrayage électrique = electric clutch. — Moment sommaire. = Absolute moment. — Nombre de tours à l'essieu moteur = r. p. m. of driving axle. — Moment fondamental du moteur à explosion = primary moment of petrol engine. — Moment supplémentaire du moteur de traction = additional moment of traction motor. — Démarrage = starting, — Vitesse normale = normal (working) speed.

power is not electrically transmitted to the driving axle. The efficiency ascertained by experiments is 10 % higher than that of a purely electric transmission. When electrically starting the diesel engine, the driving wheels must be firmly braked. It would be interesting to know whether with this system 2 driving axles can also be driven by *a single* diesel engine, as, for instance, by making the electric motor drive the second axle, and whether this has already been tried.

The distant control of railcars with electric transmission can be arranged for smaller or greater distances as required, viz :

(1) between the 2 driver's compartments of the rail motor car itself, and in connection with its own power plant only;

(2) for controlling from a driving vehicle, other vehicles being possibly marshalled in between, and acting as « distant control gear carriers »;

(3) for several railcars or trailers, with « distant control gear-carrying vehicles », i.e. for controlling several motor units from a single stand.

As a rule diesel engines are distant-controlled by means of a controller, and an electric servo-motor operating a speed regulator which in its turn acts upon the engine governor.

In order to regulate the output of the electric machines within the limits required by the diesels, adjustable resistances are inserted in the excitation circuits.

For *(a)* to *(c)* :

As a rule, no *fixed inspection intervals* are laid down for mechanical transmissions because they can cover a longer distance (150 000 to 200 000 km.=93 000 to 124 000 miles) than the engines to which they are coupled. The transmissions are generally inspected at the same time as the internal combustion engines because this seems to be good practice.

The same remark also applies to the general repairs of the electric generators and traction motors. At the complete overhaul, the commutators are cleaned and polished, and the bearings renewed. At intermediate repairs the work to be done is limited to blowing out, checking the commutators, and renewing the brushes.

So far the limits of the field of application of the mechanical, hydraulic and electric transmission cannot be fixed. The *influence* of the transmission on the *life* of the internal-combustion engines cannot yet be stated, according to the replies received from most of the Railways. *Austria* alone reports that diesel engines with electric drive show less wear than those fitted with mechanical or hydraulic transmission. When selecting the system of governing to be used with internal-combustion engines, however, the kind of transmission to be adopted should be taken into account.

Finally, nearly all Railways equip their railcars with the so-called « dead man's handle », in order to make one-man driving possible. Only the railcars for very high speeds (exceeding 120 km.=75 miles an hour) are equipped with inductive train control equipment.

* * *

V. — Steam railcars.

Steam railcars of up to date design are in operation in Germany, Egypt, Poland and Rumania.

The German steam railcars — on the *Doble* system — are fitted with high-speed reciprocating steam engines, viz. 2-cylinder compound engines with Stephenson valve gear and gear transmission.

Four-wheeled railcars are equipped with one 150-H. P. engine and eight wheeled-cars with two such engines. *Doble* railcars were described in the *Bulletin of the Railway Congress,* August 1935, pages 983-4.

Progress in the design of the Doble

railcar is still being made. An endeavour is being made to replace oil by coke, in order to make use of this by-product of carbonisation. A railcar designed to burn coke is in course of construction.

Egypt, Rumania and *Poland* possess a number of Sentinel railcars, the designs of which have been published (see *Bulletin,* August 1935, pp. 981 to 985). These steam railcars are equipped in :

Egypt, with 2 engines of 160 H. P. each,
Rumania, with 2 engines of 100 H. P. each,
Poland, with one 100-H.P. engine.

In Egypt coal is used and in Rumania and Poland, oil. The boiler pressure is 21 to 23 kgr./cm² = 299 to 327 lb. per sq. in.).

The *Doble* design includes automatic boiler control, viz. temperature control by means of thermostats, and live steam pressure control by means of diaphragm devices.

The steam railcars are operated by one man in Germany, Egypt and Poland, but not in Rumania.

On the *Doble* railcars a vertical air-cooled tubular condenser is fitted, in which the steam is condensed at atmospheric pressure. The *Sentinel* cars are not fitted with condensers.

The *Doble* cars in service in Germany can be driven from each of the 2 driver's compartments as also from a trailer by electrical remote control gear. When two steam railcars are coupled together, they cannot so far be driven from any one driver's compartment.

Egypt and Poland also use remote control, but Rumania does not.

* * *

VI. — The « vehicle ».

a) Running gear and bogies.

As regards new bogies, the Ringhoffer-Tatra design has been developed since 1935 (see figs. 28 and 29). In these so called « oscillating » bogies, the axles are arranged in such a way that each of the annular axle boxes is suspended by means of eyes at the free ends of two laminated springs, so as to allow the axles to oscillate vertically about the suspension points.

Several countries, in particular Germany, are now building their bogies by welding, as the weight is reduced without sacrificing strength.

In *Germany,* experience acquired as the result of careful investigations into the behaviour of passenger carriage bogies has been taken advantage of when designing railcar bogies. Each new type of railcar is systematically examined as regards its running gear. A new dynamometer car containing, in addition to the equipment for measuring the tractive effort, oscillation recorders for examining the running qualities of the vehicles is used for this purpose (for further particulars see Chapter IX).

As a result of these investigations it has been found inter alia that fitting shock absorbers between the bogies and the body underframe has not improved the riding. On the other hand, the addition of a fourth stage in the springing and the use of tyres coned 1 in 40 to 1 in 20 have improved the riding appreciably.

Tyres turned to a taper of 1 in 40 to 1 in 20 are also used on railcars in *Denmark, Norway, Austria, Switzerland* and *Czechoslovakia,* partly as an experiment.

The tyres used on the *German* railcars, including the high-speed cars, are made of Martin or crucible steel of special quality with a tensile strength of 80 to 92 kgr./mm² (50.8 to 58.4 Engl. tons per sq. in) as compared with 60 to 72 kgr./mm² (38.1 to 45.7 Engl. tons per sq. in.) on the other passenger carriages.

The wheels used on the railcars are generally of a design similar to those used under the other carriages.

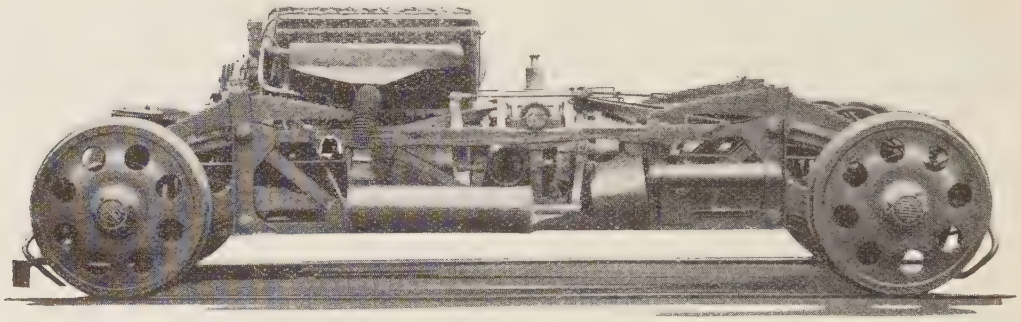


Fig. 28. — *Ringhoffer-Tatra* bogie.

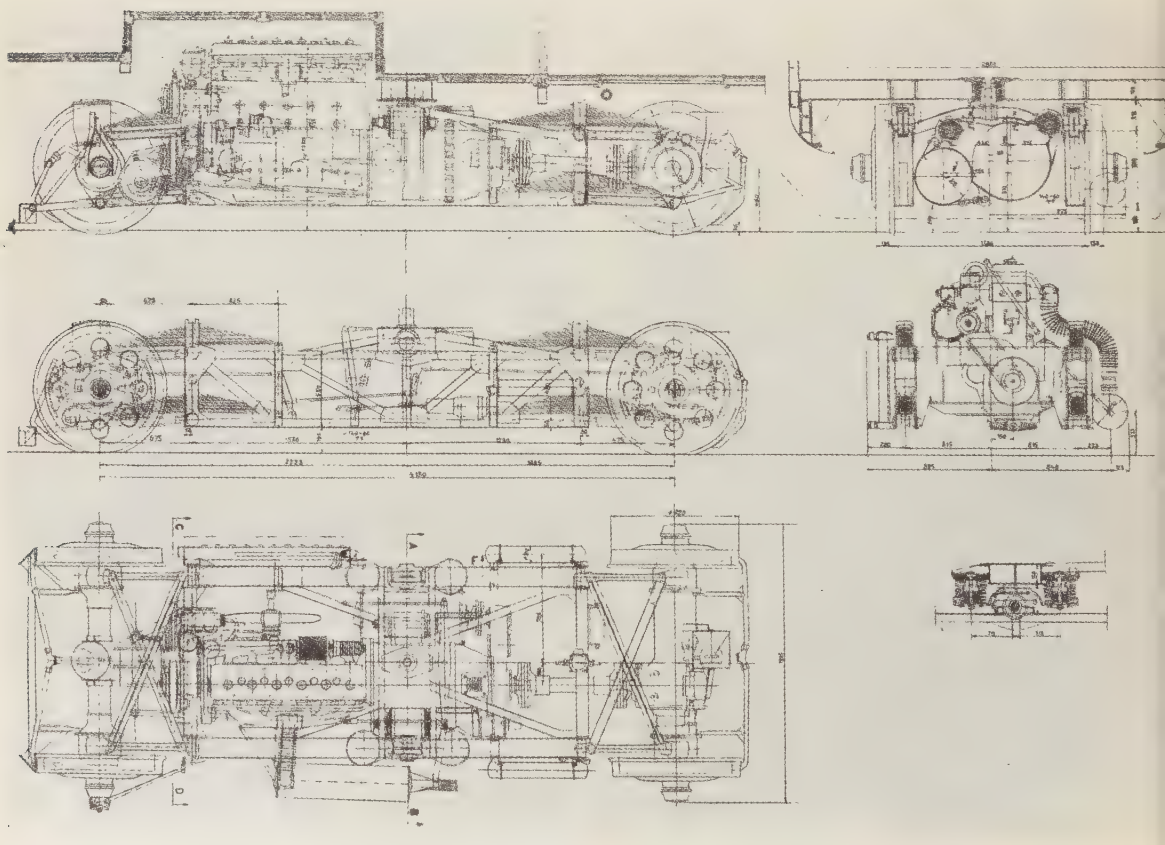


Fig. 29. — *Ringhoffer-Tatra* bogie.

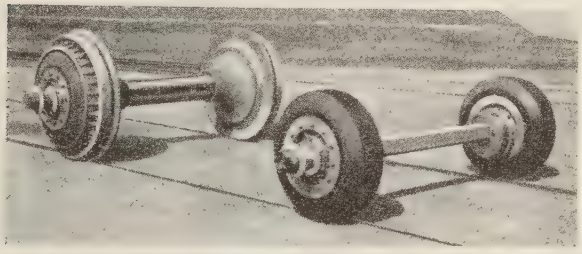
Wheels of special design are used :

— in *Austria,* on the *Austro-Daimler* railcars (fig. 30);

— in *Czechoslovakia,* on the fast railcars, for speeds of 130 km. (80.8 miles) an hour. Under this car, pressed wheels with the centre and tyre in one piece are used, this pressing also acting as a drum for the brake shoes lined with Ferrodur.

The axle roller bearings are located *between* the wheels. These wheels, which have been put into service only recently, have up to the present given good results. As a trial, Rumania has equipped two railcars with a 4-wheeled driving bogie fitted with rubber tyres. This design has given satisfactory results.

To complete the account given in the report by Messrs. Dumas and Lévy (p. 966) of the bogies used on the high-speed articulated German railcars we would add : — On the high-speed diesel-



The driving wheels are keyed to a revolving hollow axle.

The carrying wheels revolve independently round the fixed carrying axle.

Fig. 30. — Elastic wheels equipping *Daimler* railcars.

electric triple railcars since put into service the Jakob articulated (intermediate) bogies carry the electric traction motors and driving axles while the diesel engine-generator sets are carried on the end bogies. On the other hand, the articulated Jakob bogies on the *diesel-hydraulic* high-speed triplet railcars are purely carrying bogies. The coaches making up the high-speed diesel-electric triplets now under construction will have their own bogies in view of the great length of the bodies.

b) Underframe and body.

Railcars with steel underframes and wooden bodies are being built in very small number, as light cars only.

In all other cases both the underframe and body are made of metal. The reasons for adopting all-steel construction given in the earlier report by Messrs. Dumas and Lévy (p. 984) remain valid. In order to withstand the normal bending stresses caused by the vertical loads, most Railways have adopted the design in which the underframe and body are combined to form a sort of rigid tubular girder carried on two supports.

Stresses due to a collision may be absorbed either by the frame alone, or the body framing can be made to absorb them partly by building the body and frame as one unit.

In *Germany,* the body is designed to take part of such stresses. Therefore, German railcars are generally heavier than those of other countries, where a distinctly lighter construction is used at present. The heavier design has been adopted in Germany intentionally for safety purposes.

To prevent telescoping in the event of collision, the German underframe ends are strengthened. The body ends of the high-speed railcars are strengthened by using strong anti-telescoping platforms following recent passenger carriage practice, though the design used is lighter.

In Denmark the stock used on « light-

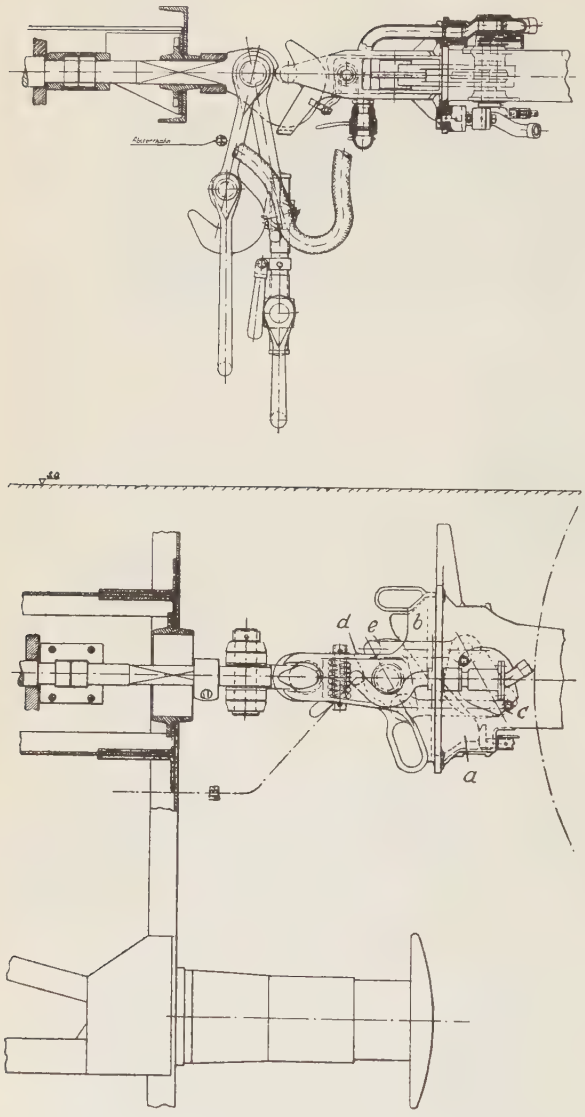


Fig. 31. — Emergency coupling used in conjonction with the *Scharfenberg* automatic coupling.

ning » trains are provided with 2 reinforced end pillars and a rail over the door to strengthen the body end.

The value of this reinforcement has been proved in service to a certain extent in *Germany* (8-wheeled railcars), *Poland* and *Hungary*. The only result of collisions in these countries between railcars and other railway vehicles was distortion of the body sides, which were easily repaired. In Denmark also, a severe collision occurred in which a railcar, which had been strengthened as explained above, proved its real shock-resisting qualities.

Owing to the greater strength of all-metal construction to resist ordinary and abnormal stresses, and its lower maintenance costs, it is generally preferred for railcars by the Railways. Both high-tensile steels and light alloys are used.

High-tensile steels, St. 52 in Germany, chrome steel 50 to 60 kgr./mm² (31.7 to 38.1 Engl. t. per sq. in.) in Rumania, and 0.2 % copper bearing steel, 40 to 50 kgr./mm² (25.4 to 31.7 Engl. t. per sq. in.) in Denmark, are used for the body frame and underframe in the form of rolled and pressed sections, and to a small extent steel castings. Copper-bearing steel sheets are used in Germany and Poland for the outside panelling.

The light alloys in current use are aluminium alloys, nickel and aluminium, and duralumin. They are used to make the interior and exterior fittings and to some extent. (e.g. in *Austria*) the outside panels.

By using these materials the weight has been reduced appreciably, which is particularly important on lines with long and steep gradients, as the fuel costs and maintenance charges are lower; however, the first cost is higher.

c) Buffing and draw gear.

Railcars, when not fitted with the standard couplings have to be provided with some device by which they can be hauled in the event of an engine failure.

For hauling high-speed railcars fitted with automatic central coupling (Scharfenberg coupling), the emergency coupling shown in figures 31 and 32 is used in Germany.

Fig. 32*a*. — Emergency coupling.

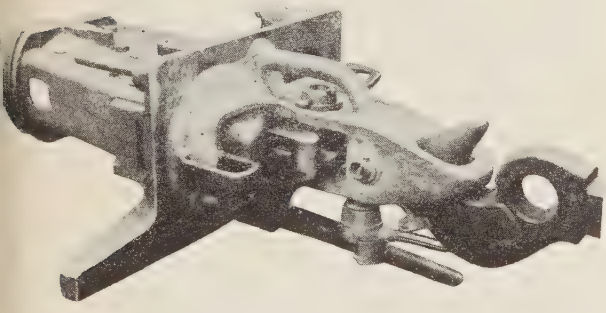


Fig. 32*b*. — Emergency coupling coupled to the *Scharfenberg* automatic coupling.

On one end of this coupling, there is a link to hook over the drawhook of the breakdown vehicle, while the other end has a coupling adapted to suit the Scharfenberg coupling. The head is supported in the correct coupling position by a spring, which maintains it against the drawbar hook. To facilitate engaging the emergency coupling, it carries a handle on each side.

When coupling up, the tapered member *a* of the energency coupling is guided into the jaw of the opposite coupling, the tapered member of which at the same time enters the jaw *b* of the transition coupling. The coupling link *c* abuts on the heart piece of the opposite coupling, whilst the coupling link of the latter abuts on the heart piece *d* of the emergency coupling. As soon as the coupling heads have made contact, the two coupling eye pieces are able to latch into the recesses of the two heart pieces. On account of the tripping of the compression spring in the coupling head of the railcar, the coupling link is advanced into coupling position, and a firm connection made between the auxiliary coupling and the railcar coupling.

One of these emergency couplings is carried on all high-speed coaches. The railcar can be hauled by a locomotive with this auxiliary coupling, without having to run at reduced speed.

If a railcar coupled to a trailer is to be driven from the latter, or if several motors cars are formed into a multiple unit and remotely controlled from the leading motor unit, all the vehicles should be equipped with remote control couplings.

For this purpose cables are sometimes provided at the end of one coach which have a coupling head on one end; the latter is plugged into the coupling socket provided on the car ends. Loose cables having couplers at both ends, which are plugged into the sockets of the two adjoining coaches are sometimes used. This method of coupling up the distant control devices is used, for example, on the twin and triple German railcars.

The German high-speed railcars at present under construction, will be equipped with automatic distant control couplings, arranged on the head of the *Scharfenberg* central coupler, and will couple up automatically, at the same time as the central coupling, the vehicles as regards distant control.

d) **Heating and ventilation.**

The various heating and ventilating methods in use on the different railways on the whole are still as described in detail in the report by Messrs. Dumas and Lévy (p. 1012).

By way of novelty, the method consisting in preheating the air in a heater by means of an oil burner, as used in Germany, may be mentioned. The warm air is forced by a blower through the distributing ducts into the compartments. The

warm air emerges below the seats into the compartment or into the corridor, while the vitiated air is mechanically exhausted through an outlet in the roof or by air extractors in the roof. The air is heated by passing it over a radiator, the water in which is heated by the automatic oil burner. In order to regulate the air temperature, the air admission valves are automatically opened or closed by thermostats.

In conjunction with this air heating, in Germany provision is made for mechanical air conditioning part of the high-speed railcars in summer, the fresh air being pulsated into the compartments through an intake and the used air being exhausted just above the floor.

The heating of railcars is still under development. No conclusive results can be taken as the basis of a final judgment at present; the selection of the best method of heating them must therefore be deferred to a later date.

e) Fire protection.

In order to avoid the risk of fire, fireproof materials are used as far as possible inside the carriages, special fire protection precautions being laid down as regards combustible substances.

In *Germany,* the engine rooms will be made in future of metal only. Any wood still in use in the engine compartments in some countries is given a coat of fire-resisting paint, or is covered with sheet iron and asbestos.

So that any fire occurring in a motor car can be fought at once, the railways fit portable extinguishers inside the coaches, as already mentioned in the report by Messrs. DUMAS and LÉVY (p. 1018). In addition, in *Czechoslovakia,* the petrol railcars are fitted with a fixed fire extinguisher above the carburettor, the jets of the extinguisher being so arranged that any fire in the carburettor could be extinguished. This extinguisher is put into operation by a strip of cellulose located immediately above the carburettor. This is immediately severed if a fire starts, the extinguisher is put into operation, the fuel shut off and in addition a warning signal is given by an alarm bell or siren.

f) Interior fitting out.

The questions touched upon by Messrs. DUMAS and LÉVY in their report (p. 1004) as to insulating the passenger compartments against noise and temperature changes have been given further attention by the railways. Nothing really novel, however, has been introduced. All that is worth mentioning in this connection is that as horizontal engines located below the floor are used in Germany on 8-wheeled cars, and in Czechoslovakia on 4-wheeled cars, the noise from these engines does not penetrate into the passenger compartments.

In order to ensure the doors of motor coaches being kept closed en route, remote-controlled or automatically-locked doors are either in use or contemplated by some Railways. In *Germany,* designs have been prepared for the use on some railcars of a system enabling the driver to remotely open and close the doors. This system has already been used for some years on the Berlin Metropolitan Railway. *Poland* and *Switzerland* already possess such equipment on a few railcars. In *Denmark* the «lightning» trains under construction are being fitted with automatically closing side doors and a pilot lamp in the driver's compartment.

The inside layout of the railcars differs according to whether they are intended for suburban services on secondary lines, local traffic round large industrial centres, or high-speed services over long distances. Some small railcars, therefore, have only one compartment; larger cars have either two compartments (one for second and one for third-class, or one for smokers and one for non-smokers), or one or two large compartments for third class and separate compartments with side corridors for second class. To

these are frequently added luggage and mail compartments and on some high-speed railcars a small kitchen is provided as well.

The interior decoration of the passenger compartments of railcars is not always the same as that adopted by the Railways for ordinary passenger carriages. On most Railways, it more ressembles motor omnibus practice, especially as regards the shape and size of the seats. In *Germany,* special importance is attached to laying out railcars comfortably, so that the proportions of recent vehicles are the same as those of corresponding steam train carriages. The provision of separate compartments for second class with the side corridor running the full length meets the demands of the passengers for greater comfort, and gives the railcars a really effective advantage in meeting competition from road motor coaches.

Luggage racks are provided in all rail motor cars, some being fitted above the body sides and some on the cross partitions. As the result of experience, only transverse luggage racks are considered satisfactory, and these will therefore be fitted in all new constructions.

Special dining compartments are not provided in the high-speed railcars in operation on some Railways, but meals prepared in a small kitchen with pantry are served to the passengers at their seats, using the folding tables provided below the windows between the seats. In *Denmark* alone, one of the luggage compartments on the « lightning trains » is used as an emergency restaurant, 3 or 4 small tables being provided.

In Germany, the method of serving meals in the passenger compartments has been found unsatisfactory, more especially on the high-speed long-distance runs, so that it has been found desirable to provide, as a trial, a special dining compartment on fast railcars. Both the triplet cars under construction, with separate compartments, and the high-speed quadruplet car, likewise under construction, will have a special restaurant compartment, the arrangement of which will follow the well tested designs of the *Mitropa* restaurant-cars.

Mail compartments are provided only on a few railcars on one or two railways. In such cases they are fitted out as a rule to suit the requirements of the Post Office.

* * *

VII. — **Brakes.**

The general principles governing the railcar brakes have already been discussed in the report by Messrs. Dumas and Lévy.

With respect to the *control of the brakes,* one important question arises at first : the possibility of graduating the release as well as the application of the brakes. The present position is that both types of brake are fairly evenly distributed between the various Railways; some Administrations also use simultaneously brakes with simple and graduated release, the brake operating diagram times as a rule remaining unaltered. When special quick-acting brakes are used, some Railways usually shorten the brake operating times.

The *Reichsbahn,* for example, is now using on railcars the graduated-release brake of the *Hildebrandt-Knorr* system. This (*Hikp*) brake, thanks to the particularly light construction of the triple valve has been adopted to suit the peculiarities of railcar operation. The triple valve on railcars running at speeds up to 120 km. (75 miles) an hour gives an increase in the pressure diagram in 5 seconds and is known as the « *Hikpt* », while the type for ultra high-speed railcars giving a rise in pressure in approximately 2 seconds is called « *Hikst* ». This triple valve occupies less room than the standard valve and its weight is 50 % lower. The cost price of the *Hikpt* triple valve and even of the *Hikst,* is approxi-

mately half that of a standard *Hikp* triple valve.

With regard to the maintenance costs of these valves, positive data are not yet available, as they have been in use too short a time. A reduction in the maintenence costs of the *Hikpt* and *Hikst* valves as compared with the *Hikp* triple valve may be anticipated, however, as certain parts incorporated in the latter valves are not fitted with the new (minimum-pressure valve, isolating cock).

On new and large vehicles (multiple units) and vehicles for special traffic, e.g. suburban or express services, electric brake control is used in conjunction with pneumatic control, all the valves being operated simultaneously. At the same time a lighter and simpler driver's brake valve can be fitted on all railcars, as so far they are operated in small rakes. Electrically-controlled brakes are also used in *Poland* and *Czechoslovakia,* though in the latter country only on the « Slovak Arrow » railcar.

Brief mention should be made also of a brake control system used — only in certain cases — in conjunction with pneumatic control, viz. hydraulic control (Lockheed brake) in which oil under pressure is the transmission fluid ; in this connection, the hydraulic hand brake of the *Reichsbahn* should be mentioned. This brake has only been used in connection with drum brakes. One requirement in the case of oil-pressure brakes is that the blocks must not slack off on stationary vehicles, for instance through leakage in the pipes, even after prolonged periods. Special safety devices (mechanical locks) must therefore be incorporated.

On some of the vehicles the transmissions are also used for braking, e.g. the hydraulic *Voith* system with which no special auxiliary devices are required to produce a braking effect. On the other hand, the practice, customary in road motor car operation, of using the engines as compressors on long downhill runs, is not in use, except on the 3 light railbuses of the *Reichsbahn.*

As regards the question as to by what means the railcars are braked, the bulk of them are fitted with shoe brakes, while a few railways only use on a few railcars, the composition-lined brake bands acting on special brake drums or discs.

Most railways design the brake gear to get a brake block pressure of roughly 80 % of the tare weight.

An arrangement by which the braking effort exerted by the blocks can be automatically regulated to suit the load, this braking pressure also finally reaching 80 % of the weight of the loaded vehicle, is not used by any Administration. The Reichsbahn has used this system so far on light railcars, the braking power of which drops heavily when fully loaded.

The Swiss railcars which are braked to about 120 % of the tare weight with 5 kgr./cm² (71 bl. per sq. in.) pressure should be mentioned. Diesel railcars of the *Egyptian State Rys.* are braked for emergency cases (direct action brakes) to 160 %; similarly a high-speed bogie railbus of the *Hungarian State Rys.* is braked to 152 %.

As regards preventing the wheels being skidded under heavy brake applications, only the driving wheels are sanded, if possible.

On most vehicles the pressure produced in the brake cylinder fitted on the underframe or alternatively in two brake cylinders fitted on the bogie, is distributed over all the wheels by an appropriate brake rigging, made of high-grade steel, each wheel being braked by two blocks. Most of the railways use one-piece brake blocks, though on two Railways (*Jugoslavia* and *Germany*) divided blocks are used, for which certain specific surface pressures must not be exceeded. Slack adjusters are also incorporated in the brake rigging on various Railways.

Brakes with *special friction linings* have been adopted by a number of Railways, mainly to reduce the weight by

simplifying the rigging and using small cylinders and lighter levers. In so doing the intention was to obtain all-round lighter construction of railcars.

The *Austrian Federal Rys.* use drum brakes with segments acting externally, in order to suit the constructional features incorporated in the *Daimler* wheel.

Apart from getting the lightest possible construction, these Railways are using drum brakes instead of block brakes on high-speed railcars in order to reduce the braking distances.

As regards constructional details, we may first of all put on record that the classic automobile pattern, i.e. with internal braking segments, has been used on a few light railcars only, such as the « Slovak Arrow » built to run at 130 km. (80.8 miles) an hour (figs. 33 to 35).

Each bogie is equipped on each side with a brake cylinder which, by means of compensating rigging, forces the brake cheeks between the wheels against the inner side of the tyres, which then acts as the braking surface. Literally speaking, the « classic automobile type of brake » has been applied to a few light railcars of the *Reichsbahn;* as with road motor car brakes, the two brake cheeks are forced by means of a toggle against the internal surface of the brake drum; these four-wheeled railcars carry two brake cylinders.

Apart from this internal cheek brake, used only on a few light railcars, the type of brake acting externally upon special brake drums has been used on a larger scale (figs. 36 to 41).

With these brakes the drums are fixed on the wheel centre, on the inside or outside; the driving bogies are mostly provided with outside one-piece drums, owing to the presence of the engines and transmission gear ; when separate brake drums are used inside the wheels, narrower bogies can be used.

All drum brakes have up to the present shown the one common feature, that the braking force is not produced in one or two brake cylinders as with most block brakes, and distributed by means of rigging, but is transmitted by separate cylinders acting directly upon the corresponding brake blocks. In this connection, investigations have been made to ascertain whether light alloys might not be used for the cylinders instead of cast iron.

In another design, the two shoes acting upon one drum are applied by a horizontal double brake cylinder above the drum. On all designs of the *Reichsbahn,* the brake blocks are constantly guided by means of a special mechanism so as to prevent the shoes from dragging on the braking surface when the brake is released. In order to allow the service brake test being carried out on internal or concealed drums, each bogie of the *Reichsbahn* has a special indicator device actuated by the brake cylinder pressure. Contrariwise, with ordinary block brakes, the way the block bears upon the tyre surface, more visible in this case, provides a sufficient indication as to the effective working of the brakes.

Some railcars of the *Reichsbahn* and a series of trailers provided with distant control gear have been equipped with disk brakes, i.e. braking disks are fitted on the inside and outside of each wheel (figs. 42 to 44). Each wheel has four brake shoes (each pair of which is forced by a double brake cylinder against the disks on one wheel, like a pair of pincers.

The advantage of this system over drum brakes is that heat produced in braking (conversion of the live energy into heat) is no longer fed into an annular body (drum) but to two flat disks, the larger exposed surface of which dissipates the heat better.

As regards air compressors, the following may be said : The *Swiss Federal Rys.* currently use high-speed (2 850 r.p.m.) rotary compressors with separate electric drive. The steam-operated air pumps

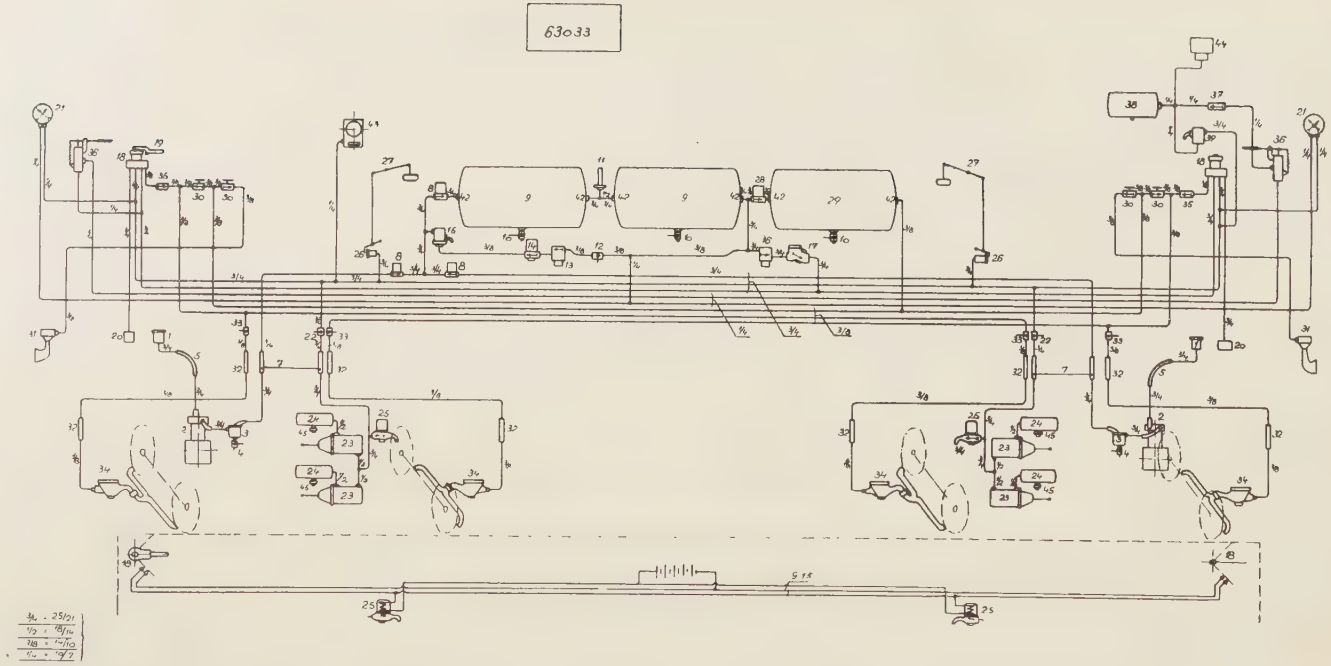


Fig. 33. — Brake with interior segments, of the fast railcar « Slovak Arrow ».

Diagram of *Knorr* brake.

1. Suction filter.
2. Compressor.
3. Air filter.
4. Drain cock.
5. Rubber hose in suction piping.
7. Rubber hose, 3/4 ".
8. Brake valve.
9. Main air reservoir 100 l. (3.5 cu. ft).
10. Drain cock, 1".
11. Safety valve.
12. Check valve.
13. Air filter.
14. Control of s parator.
15. Separator.
16. Air filter.
17. Pressure reducing valve.
18. Driver's valve.
19. Handle.
20. Noise damper.
21. Double pressure gauge.
22. Stop cock.
23. Brake cylinder.
24. Auxiliary reservoir 7 l. (0.25 cu ft).
25. Electro-magnetically controlled valve.
26. Emergency brake valve.
27. Hand operation of emergency brake.
28. Reducing valve.
29. Auxiliary reservoir, 1 l. (61 cu. in.).
30. Push-button valve.
31. Signal horn.
32. Rubber hose, 3/8 ".
33. Stop cock.
34. Sander.
35. Check valve.
36. Safety valve.
37. Pressure reducing valve.
38. Auxiliary reservoir.
39. Separator.
42. Threaded connection.
43. Speed recorder
44. Regulating valve.
45. Release valve.

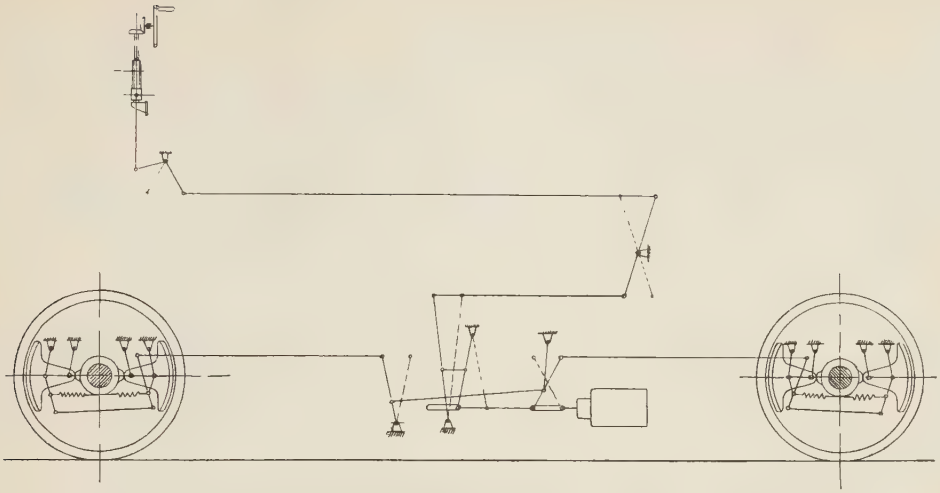


Fig. 34. — Brake with interior segments, of the railcar « Slovak Arrow ».

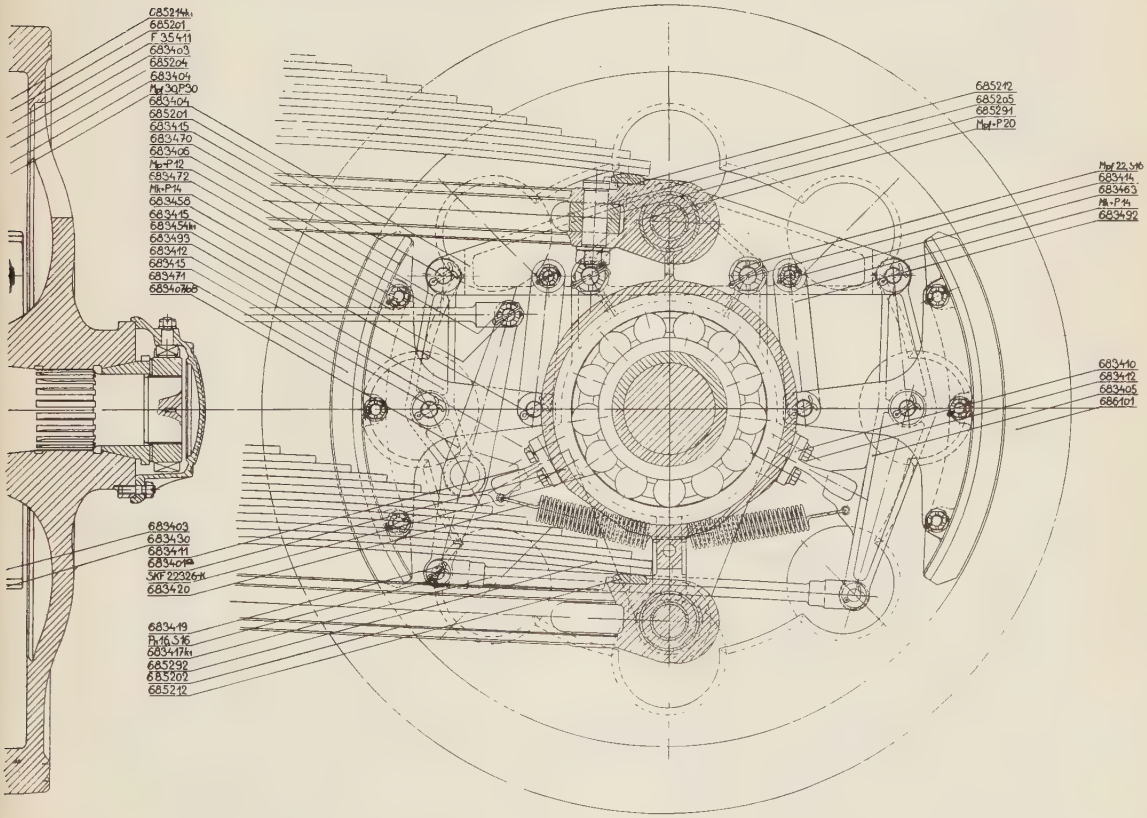


Fig. 35. — Brake with interior segments, of the railcar « Slovak Arrow ».

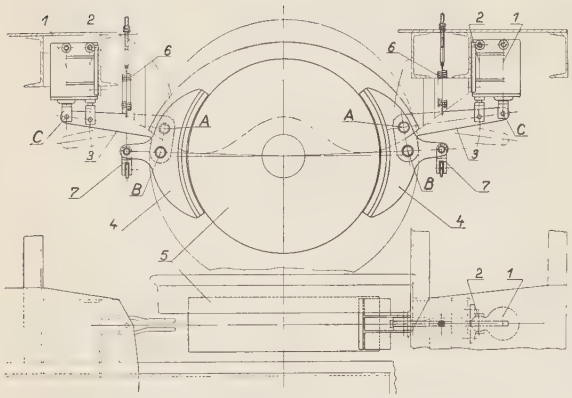


Fig. 36. — Diagram of brake with outside drums. Arrangement with single brake cylinder and cranked levers.

Explanation :

1. Compressed air brake cylinder.
2. Oil-pressure brake cylinder (for hand brake).
3. Brake lever.
4. Brake block.
5. Brake drum.
6. Check spring.
7. Guiding device.

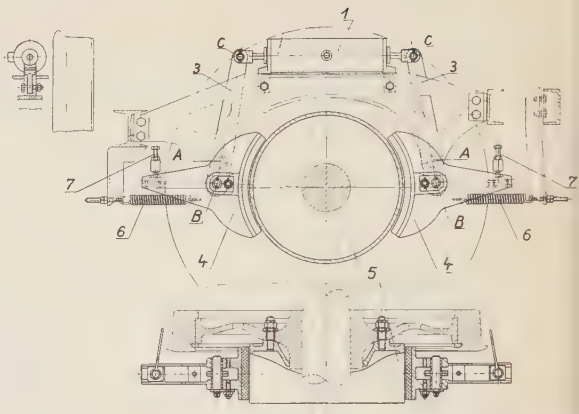
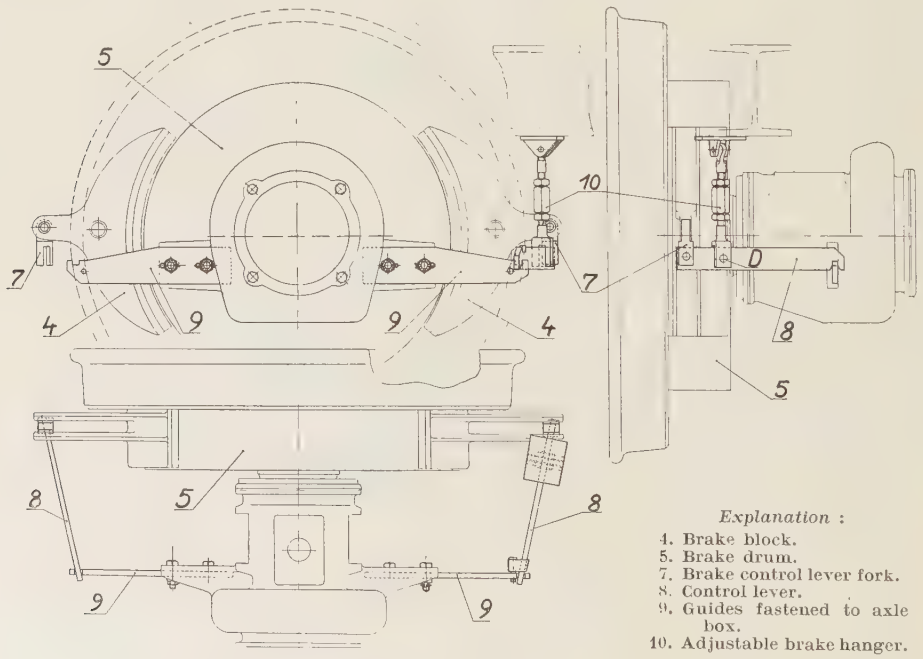


Fig. 37. — Brake with inside drum (without oil-pressure brake cylinder). Arrangement with double brake cylinders and straight levers.

Explanation :

1. Double brake cylinder, for compressed air.
3. Brake lever.
4. Brake block.
5. Brake drum.
6. Check spring.
7. Adjusting screw for guidlng device.



Explanation :

4. Brake block.
5. Brake drum.
7. Brake control lever fork.
8. Control lever.
9. Guides fastened to axle box.
10. Adjustable brake hanger.

Fig. 38. — Operation of brake shoes on 8-wheeled railcars.

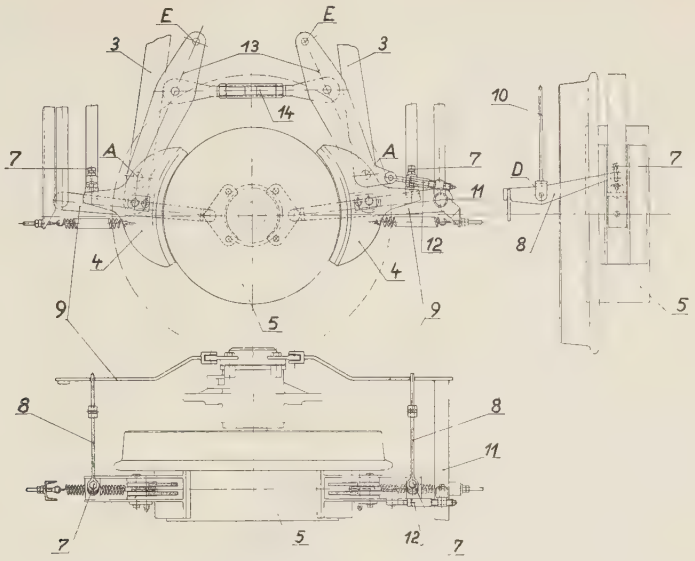


Fig. 39. — Operation of brake shoes on 4-wheeled railcars.

Explanation :

3. Brake lever.
4. Brake shoe.
5. Brake drum.
7. Control lever adjusting screw.
8. Control lever.
9. Fastening of guide to axle box.
10. Brake hanger.
11. Control pipe.
12. Connecting bar.
13. Fixed-point lever.
14. Adjusting rod.

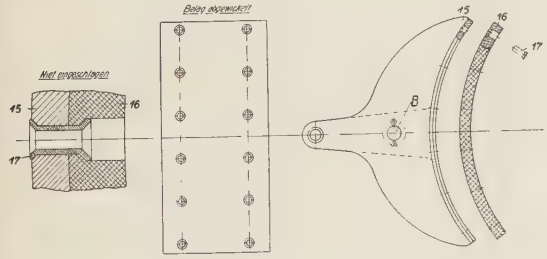


Fig. 40. — Details of brake shoe : shoe lining fastened by rivets.

Explanation :

15. Lining holder.
16. Lining.
17. Hollow copper rivet.

Note. — Niet eingeschlagen = countersunk rivet. — Belag abgewickelt = lining removed.

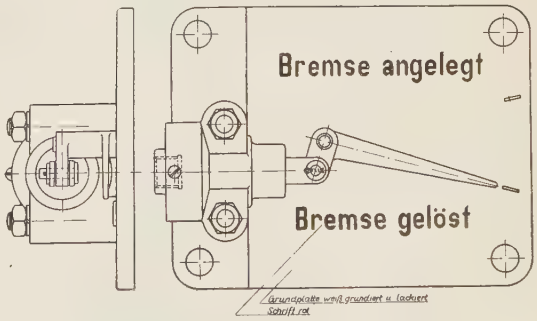


Fig. 41. — Stroke indicator.

Note. — Bremse angelegt (gelöst) = brake applied (released). — Grundplatte weiss grundiert und lackiert = plate with white background, enamelled. — Schrift rot = inscriptions in red.

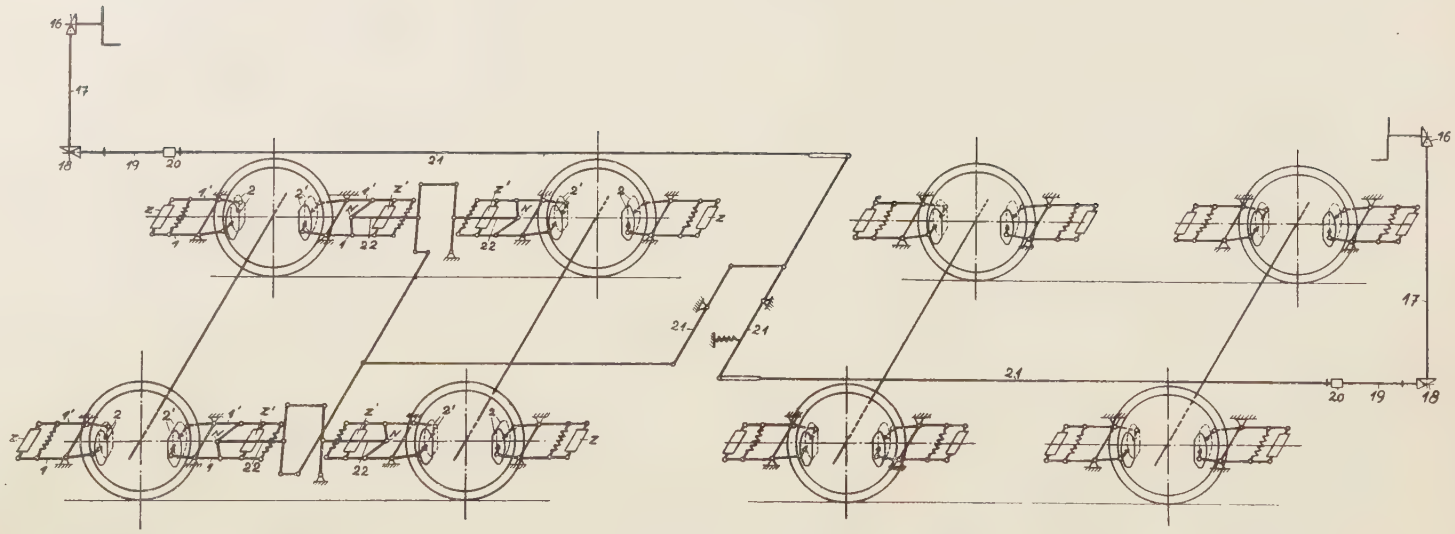
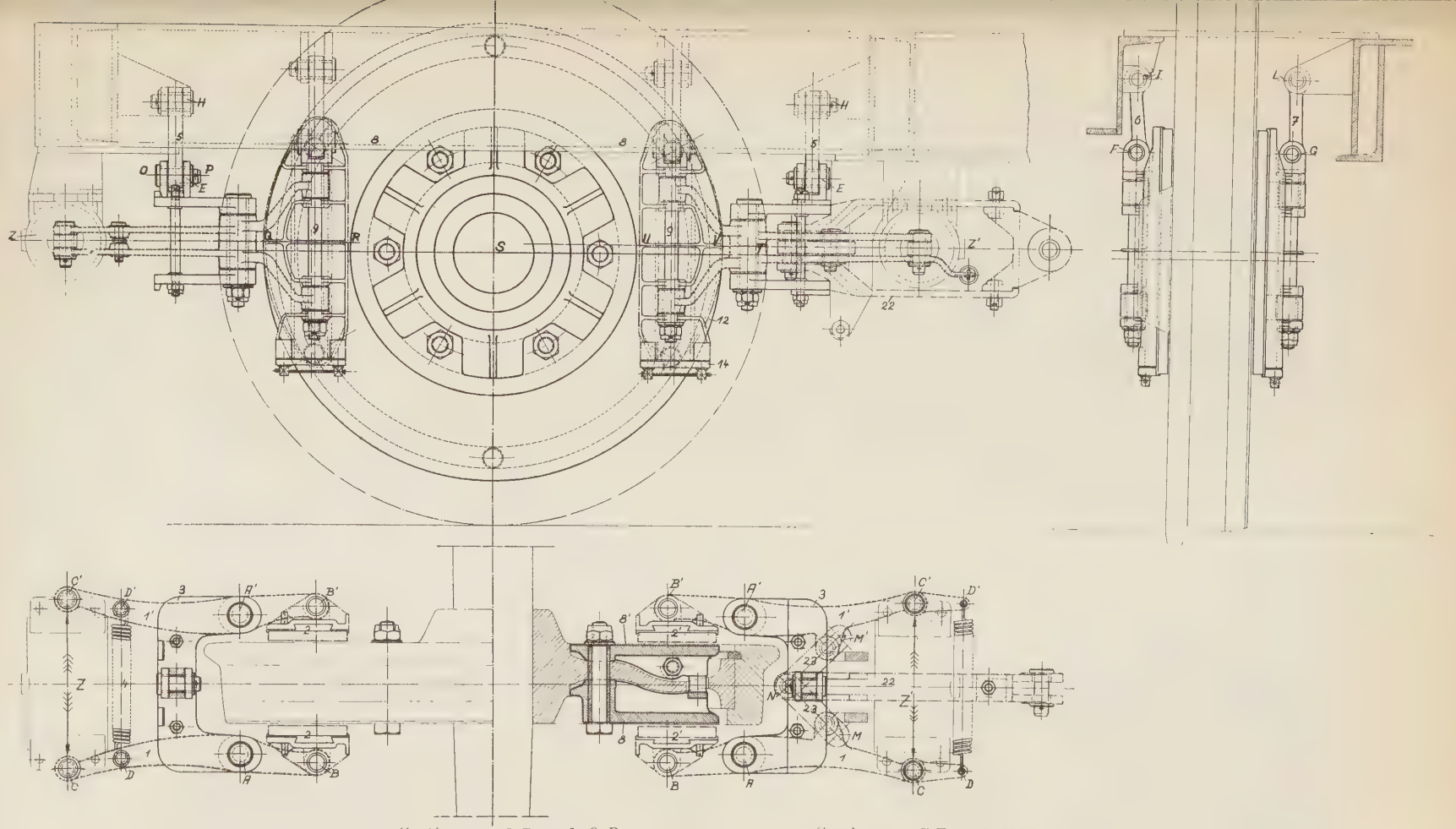


Fig. 42. — B.S.I. disk brake. — Diagram of arrangement of brake shoes and brake disks in relation to the vehicle.

Explanation :

1 and 1'. — Brake lever.
2 and 2'. — Brake blocks.
15. Brake hand wheel.
16. Bevel gear.
17. Shaft.
18. Bevel gear.
19. Bolt.
20. Nut of bolt.
21. Rigging.
22. Operating rod.
Z and Z'. Double brake cylinder.
N. Point from which the operating rod 22 is driven.



Section on O-P and Q-R. *Section on S-T and U-V.*

Fig. 43. — B.S.I. type disk brake. — General design.

Explanation :

1 et 1'. Brake levers
2 and 2'. Brake cheeks.
3. Support of brake levers.
4. Check spring.
5, 6, 7. Brake hangers.
8. Outside brake disks.
8'. Inside brake disks.
9. Hinge bolt.
12. Brake cheek lining holder.
14. Counter plate.
22. Control rod.
23. Lever.

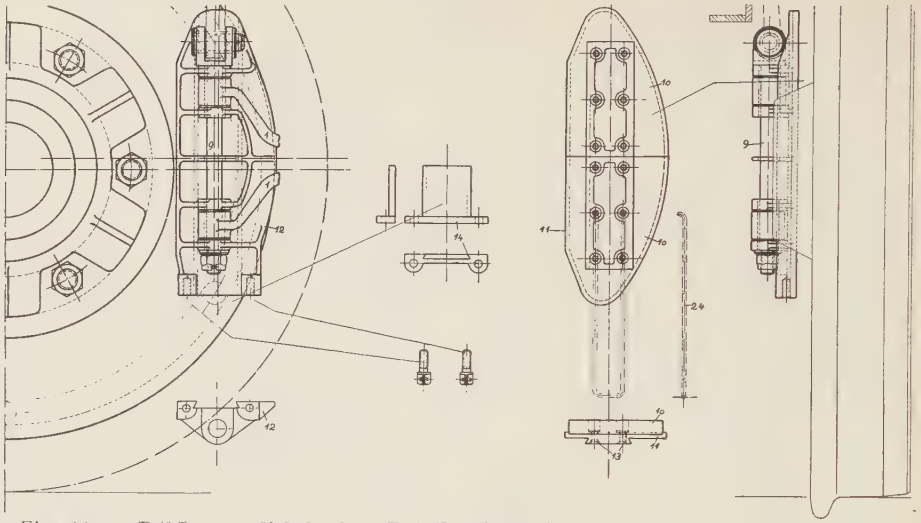


Fig. 44. — B.S.I. type disk brake. Details of braking elements (cheek and lining).

Explanation :

1. Brake lever.
9. Hinge bolt.
10. Brake lining.
11. Brake lining holder.
12. Brake cheek.
13. Copper hollow rivets.
14. Counter plate.
24. Round wire.

on the German railcars make 150 strokes per minute, the steam pressure being 25 to 30 kgr./cm² (356 to 427 lb. per sq. in.).

The air compressors, on some Railways, are carried in the carriage body, as far as the designs mentioned in the last report are concerned, while on others they are accomodated in the bogies, in most cases without any special precautions for damping the vibrations and reducing the noise. One of the Railways uses special rubber packings for this purpose.

The compressed air in most cases is at a pressure of 7 to 8 kgr./cm² (100 to 114 lb. per sq. in.), while on the *Reichsbahn* high-speed railcars the pressure in the main reservoir is 10 kgr./cm² (142 lb. per sq. in.).

The Railways only little investigated compressor design from the point of view of lightness of such equipment; some Railways have not completed their work in this respect as yet. All the Railways agree that light metals have not found their use up to now for piping and reservoirs.

Approximately half of the railways consulted not only supply air to the brake from the main reservoir, but also to other air consuming equipment (e.g. sanders, whistle, window wipers). In order to prevent the brake being affected by this other equipment using too much air, special air reservoirs are fitted on other Railways; the capacity is made still greater when air-operated gear, such as couplings, reverse gear, is fitted.

Some Administrations in addition to the acceptance trials, make brake tests to determine the stopping distance on the level or occasionally on down gradients. In so doing retardations have been recorded by some railways of from 0.6 to 1.6 m. (1.18 to 5.25 ft.) per sec. per sec.

In order to determine the parameters corresponding to the results recorded during these trials, the latter are com-

pleted by bench tests, in which the pressure rise in the brake cylinder, for example, is measured. The *Reichsbahn* also measures the brake block pressure during stationary tests, in order to determine the losses in the brake rigging (rigging efficiency), as well as propagation time of the brake action. When still further information about the brake is required, the decelerations are measured during the runs through the entire braking process.

The further question has been raised in connection with cars carrying brakes with special fittings (drum brakes), as to whether these railcars can also run over steep gradients. In reply the *Austrian Federal Rys.* state that they are operating over 1 in 36 gradients with such brakes, with good results. In *Poland* also light railcars run over such steep gradients.

The Reichsbahn is of the opinion that cars with special brakes (drum brakes) should not be run over long gradients exceeding 1 in 12.5. According to its experience, very considerable heating of the drums and severe wear of the brake linings must be allowed for on steeper gradients, e.g. of 1 in 25. The disk brakes described above behave better in this respect.

With regard to the overheating conditions, let us briefly refer to the importance of this question in brake design. It must be regarded as the most important point in designing the brakes of high-speed vehicles. The quantity of heat to be dissipated by the brake parts (wheel tyres or brake drums or brake disks) in a very short time increases with the square of the speed, whilst the size of the brake parts has to be kept within reasonable limits owing to the little space available.

The retardation obtained from *high-speed railcar brakes* must be the greater as the speed rises, to ensure the vehicles stopping within the minimum interval between the distant and the home signals, with a safety margin.

The electro-magnetic rail brakes, fitted for this purpose in addition to the usual types of brake, have been briefly described as regards their design and action as « emergency brakes » in the 1936 report. Let us mention in this connection the following result obtained with the electro-magnetic rail brake : on the *German Railways* with a high-speed railmotor car the braking distance was reduced by about 300 m. (984′) from a speed of 160 km. (100 miles) an hour.

The German Railways have perfected both the electro-magnet operating gear and the shape of the shoes with a view to increasing the brake efficiency. Thus the shoes have been subdivided into several sections in order to minimise deformation due to heating while sliding over the rails. In future, shoes divided into a number of small parts are to be employed exclusively for this reason.

It is true that in regular working, the use of the magnetic rail brake offers serious drawbacks. The weight of the vehicles is increased, and working costs are increased due to battery recharging; in the workshops, some additional expenditure is also necessary as the magnetic brakes have to be overhauled and the magnetic shoes renewed.

Among the countries covered by this report, *Poland* also employs the electro-magnetic rail brake, mainly as an emergency brake in conjunction with other systems.

With regard to the development of new brakes, the following is worthy of mention :

Already in the 1936 report it was stated that various Administrations preferred an improved type of block brake to the drum brake. The former is so designed that the constant adhesion between wheel and rail is utilised as far as possible by the braking effort between block and wheel tyre. For a brake with cast iron blocks, this means a variation of the force with which the blocks are pressed home, able to compensate the increase of the

friction coefficient accompanying the speed drop.

Such a brake has been provided in a simple manner on the small railbuses in use on the *Hungarian Railways*. The originally high pressure found in the brake cylinder in order to obtain a braking coefficient of over 100 % is gradually reduced by the driver as the speed falls.

The *Polish Railways* report in this connection that the brake pressure is steadily diminished with the speed. No further particulars about the design used have, however, been supplied.

The *Deutsche Reichsbahn* have also developed an improved block brake, by which the braking force is adjusted in two cylinders to suit the adhesion. This principle had already been incorporated in the German *Kunze-Knorr* high-speed brake, in which the pressure of the brake blocks, about 125 % at high speed, is reduced to normal value as soon as the braking torque exceeds a certain magnitude when one cylinder is emptied by means of a suitable device.

The pressure exerted by the blocks in this (*Kksbr*) brake at high speed, however, does not make full use of the adhesion, and the effort exerted by the blocks has therefore been increased at high speed from 125 % to 200 %, the brake power being reduced in one stage to the normal value at a given speed.

For new high-speed railcars such a « *Hildebrand-Knorr* » (Hikssbr) brake will be designed as follows (fig. 45).

The brake cylinders are fed through a « pressure converter » (pressure reducing valve) from an « auxiliary air reservoir » which is under the same pressure as the main reservoir. The pressure reducing valve is influenced on the one hand by the pressure, governed by a main control valve, in an « auxiliary pre-control reservoir », and on the other hand by a speed regulator. The brake may be applied and released gradually in the normal way like all *Hildebrand-Knorr* brakes. For quick-action or emergency braking, a high cylinder pressure will give a powerful braking effect at speeds above 60 km. (37.3 miles) an hour, so as to take full advantage of the adhesion, thus reducing the braking length, whereas below 60 km. an hour, the cylinder pressure drops.

The brake design for high-speed railcars, just described, will include, in addition, electric brake control, which will allow of gradual braking reduction being obtained quickly and instantaneously ; operation of the brake will thereby be facilitated when vehicles are operated as multiple-units.

The individual components of this (*Hikssbr*) brake work as follows :

When the driver uses the air brake in the usual way (pneumatic control), the *Hikst* control valve (*34*) is placed in the braking position. Compressed air flows into the pre-control reservoir (*35*) and, by means of a double check valve (*36f*) towards the pressure reducing valve (*39*). If at a given moment the driver stops the further pressure drop in the pipe line, the *Hikst* main control valve moves into the « no braking position » and stops the further supply of air to the auxiliary pre-control reservoir. In the *electrically*-controlled brakes, the driver closes the magnetic circuit of the brake valve by depressing the lever catch; the valve then opens and compressed air passes into the pre-control reservoir (*38*).

With electrically and also pneumatically-operated brakes a pressure, which may be regulated at will, is set up in the pre-control reservoir (*38*) or (*35*) and hence in the chambers below the piston set in the pressure reducing valve (*39*); in the event of pneumatic control this pressure invariably corresponds to the momentary pressure drop in the main supply pipe and may be increased to 3.6 kgr./cm² (51 lb. per sq. in.). In the electrically controlled brakes, the pressure is limited to 3 kgr./cm² (42 lb. per sq. in.). The pressure in the pre-control reservoir forces the set of pistons upwards, thus closing an exhaust valve and opening an admission valve. Compressed air flows through the large section of the admission

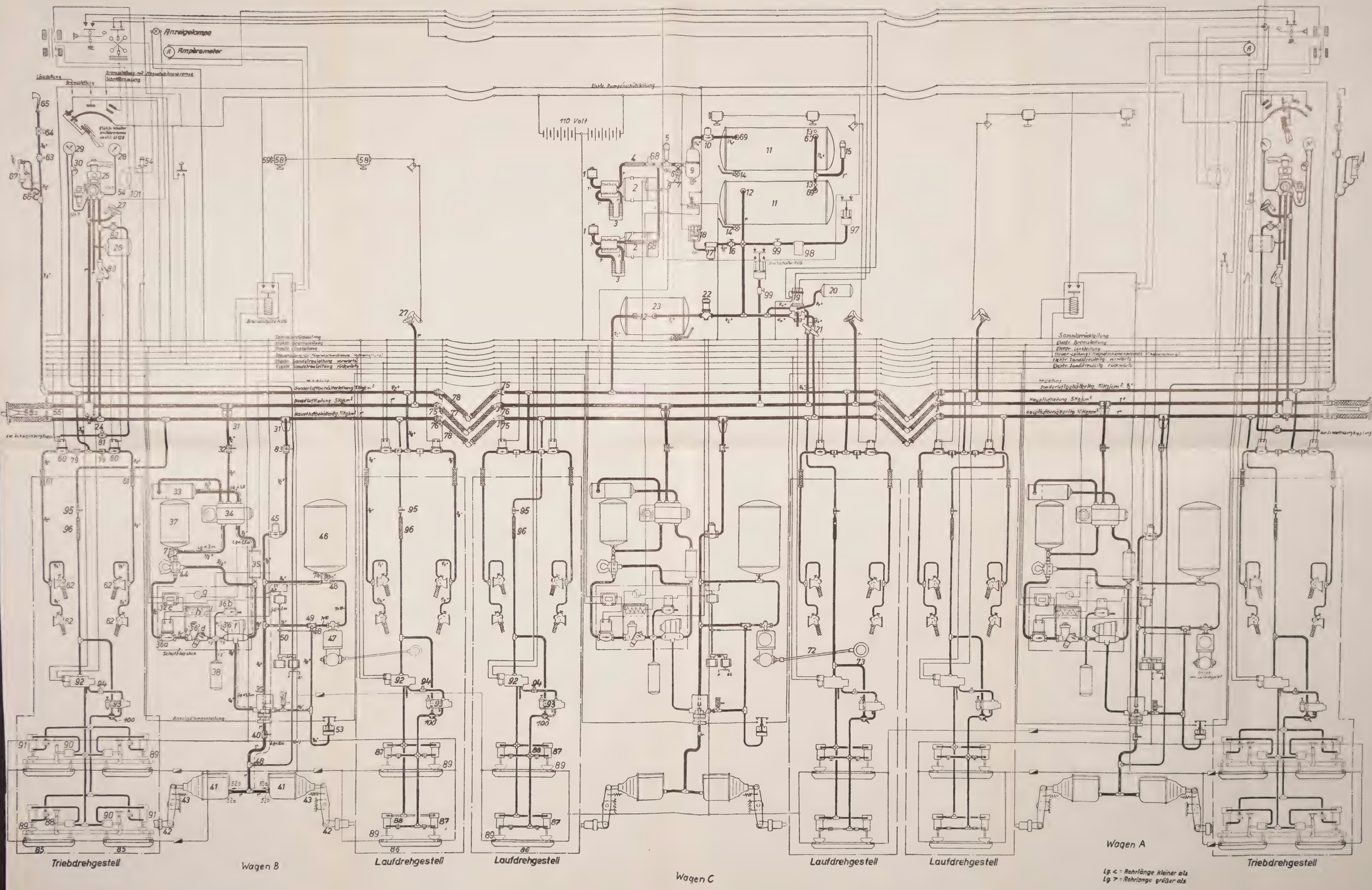


Fig. 45. — Hildebrand-Knorr (Hikssbr) brake for fast railcars.

Explanation of German terms: Anzeigelampe = pilot lamp. — Triebdrehgestell = motor bogie. — Wagen = Carriage. — Laufdrehgestell = carrying bogie. — Lg < = Pipe length smaller than... — Lg > ... = Pipes length greater than...

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valve from an auxiliary reservoir into the brake cylinders (*41*). As soon as the pressure in the brake cylinder, and hence that acting upon a piston of the pressure reducing valve has become so large as to overcome the pressure in the pre-control reservoir, and consequently to overcome the pressure upon the set of pistons in the pressure reducing valve, taking into account the relative piston surfaces, the piston set will move downwards and close the admission valve, without at the same time opening the exhaust valve. The air supply from the auxiliary reservoir to the brake cylinders is cut off and the braking effect is limited to the stage reached. In this manner the pressure in the brake cylinders may be increased up to full pressure.

The maximum value of the brake cylinder pressure in a full brake application is regulated according to the vehicle speed, by means of a centrifugal brake pressure regulator (*47*) which is driven by means of bevel gears and a telescopic cardan shaft from the axle. At high speeds (over 60 km. = 37.3 miles an hour) the centrifugal brake pressure regulator opens an exhaust valve and closes an admission valve. A chamber in the pressure reducing valve is thereby emptied to the atmosphere through the reversing cock (*49*). The action of the air pressure from the pre-control reservoir to the set of pistons in the pressure reducing valve will thus no longer meet any counter-pressures. At equal maximum pressure in the pre-control reservoir, a higher brake cylinder pressure is thus used *without* compensating pressure than *with* compensating counter-pressure in order to cause the return of the whole piston set and hence the closing of the admission valve in the pressure reducing valve. This compensating counter-pressure, however, is set up as soon as the running speed drops below 60 km. (37.3 miles) an hour, because in such an event the centrifugal brake pressure regulator (*47*) will close the exhaust valve and open the admission valve through which the compressed air will now flow from the auxiliary reservoir (*46*) into a chamber of the pressure reducing valve. Owing to the compensation unloading the piston set in the pressure reducing valve the admission valve will now close under a lower brake cylinder pressure, as also under an equal maximum pressure in the pre-control reservoir.

The relative pressures and piston surfaces are so selected in pneumatically-controlled high-speed braking that the brake cylinders be fed at high speeds at a 6.5 kgr./cm.^{2} (92 lb. per sq. in.) pressure, and at low speeds at 2.5 kgr./cm^2 (35.5 lb. per sq. in.), this being equivalent to braking at 200 and 75 % respectively. In electrically-controlled braking the maximum ultimate pressure amounts to about 5 kgr./cm.^{2} (71 lb. per sq. in.).

High-pressure braking is indicated to the driver by a pilot lamp lighting up; at 75 % braking power this pilot lamp is extinguished.

When the reversing cock (*49*) is changed over from position « SS » into position « P », braking will remain limited to 75 % at all speeds.

With quick-acting braking, the air of the main pipe exhausts to atmosphere through wide orifices in the driver's valve. The switch of the electric brake valve is furthermore automatically closed in this position, and the electro-magnetic rail brake applied.

To sum up, as regards the Chapter on « Railcar brakes », it should be said that the majority of the railcars are equipped with ordinary block brakes giving the usual braking coefficient of 80 %. Drum brakes with special linings and special designs of brake (e.g. electro-magnetic rail brakes) are used on a smaller scale, while block brakes whith high braking coefficient, of known designs, are only being introduced.

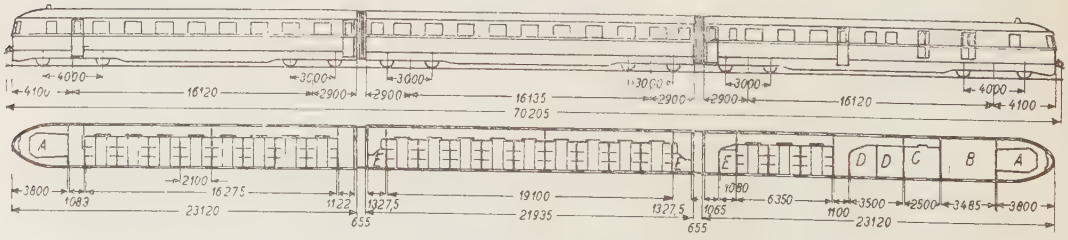
* * *

VIII. — Noteworthy types of new railcars.

Germany. — The capacity of the twin and triple high-speed railcars (fig. 46) already dealt with in the report by Messrs. DUMAS and LÉVY published in the *Bulletin of the Railway Congress*, August 1935, has not been found sufficient in all cases. On several lines, trains are now being run consisting of two double-unit sections, coupled together. Further high-speed rakes of three units, and two of four vehicles are now in course of construction. With the former, the carriage bodies have been lengthened as far as possible, without unduly restricting the width. As such considerable lengthening was not possible whilst retaining the articulated (*Jakobs*) bogies, which had behaved well, the new high-speed triplets will be carried on two separate bogies. One advantage of this arrangement is that the individual units can be handled more easily in the shops (fig. 47). The power plant design and arrangement are the same as that of the diesel-electric high-speed triplets already in service (2×600 H. P.).

An even greater available capacity is given by the four-unit high-speed railcars, the entire power plant of which is located in one end vehicle (power unit). This end coach also contains a luggage compartment and a mail compartment. The three remaining vehicles

Fig. 46. — 2 × 600-H.P. fast triplet of the *Deutsche Reichsbahn.*



A. Engine room and driver 's compartment. — *B.* Luggage compartment. — *C.* Mail compartment. — *D.* Kitchen. — *E.* Lavatory.

120 second-class seats. — Maximum speed : 160 km. (100 miles) per hour.

Fig. 47. — 2 × 600-H.P. fast triplet, « Köln » type, of the *Deutsche Reichsbahn.*

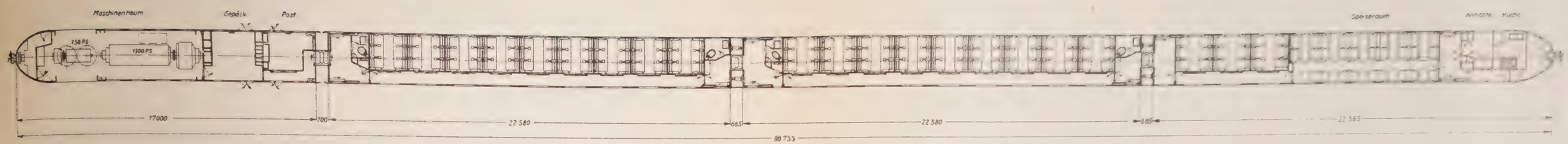


Fig. 48. — 1300-H.P. fast diesel-electric quadruplet (100 miles an hour). *Deutsche Reichsbahn.*

Note. — Maschinenraum = Engine room. — Gepäck = luggage. — Speiseraum = Restaurant. — Anrichte = pantry. — Küche = kitchen.

Fig. 49. — 360-H.P. 8-wheeled railcar for branch lines, *Deutsche Reichsbahn.*

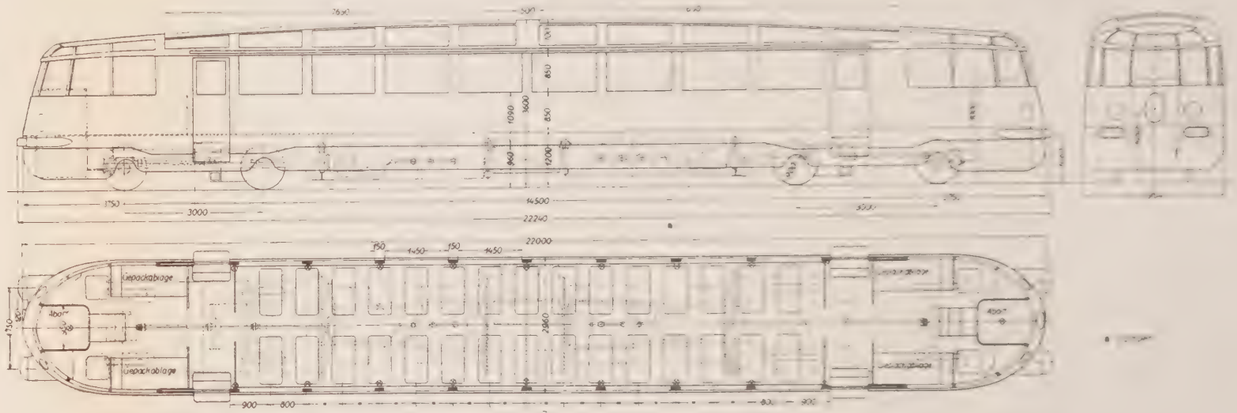


Fig. 51. — 8-wheeled diesel-hydraulic observation railcar. *Deutsche Reichsbahn.* *(60 seats.)*

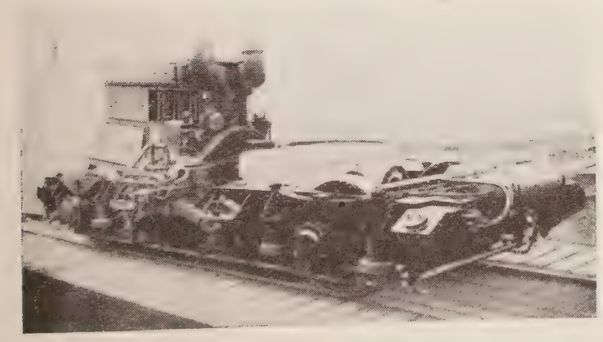


Fig. 50. — Motor bogie of 360-H.P. railcar for branch lines, *Deutsche Reichsbahn.*

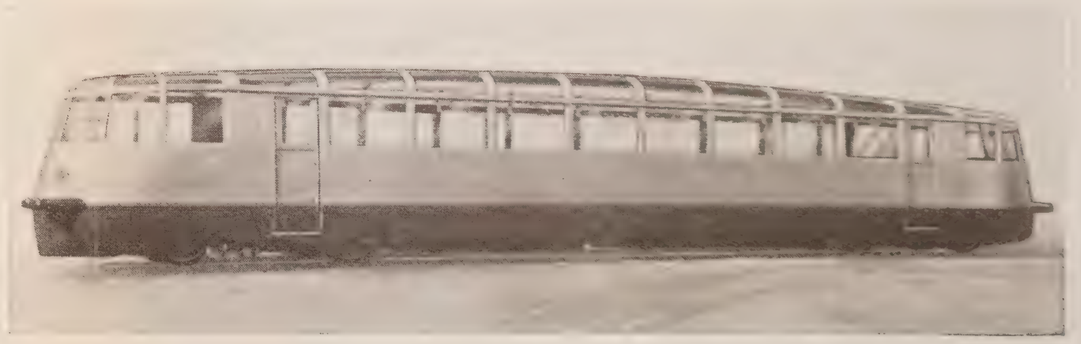


Fig. 52. — 8-wheeled diesel-hydraulic observation railcar. *Deutsche Reichsbahn.*

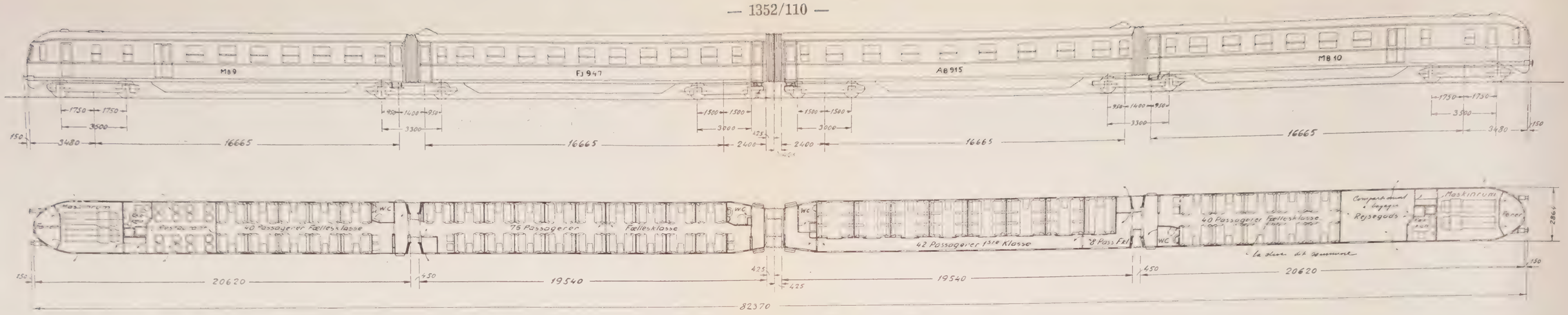


Fig. 53. — Fast quadruple railcar of the *Danish State Railways*.

Note. — Foellesklasse = so called common class. — Rejsegods = luggage. — Forer = driver. — Maskinrum = engine room. — Kokken = kitchen.

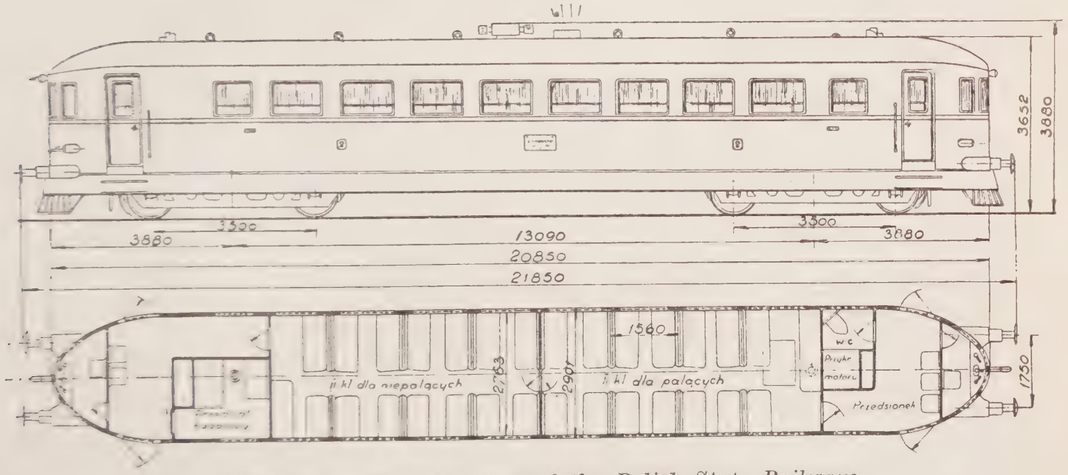


Fig. 54. — Recent railcar of the *Polish State Railways*.

Fig. 55. — Diesel-mechanical railcar of the *Swiss Federal Railways*.

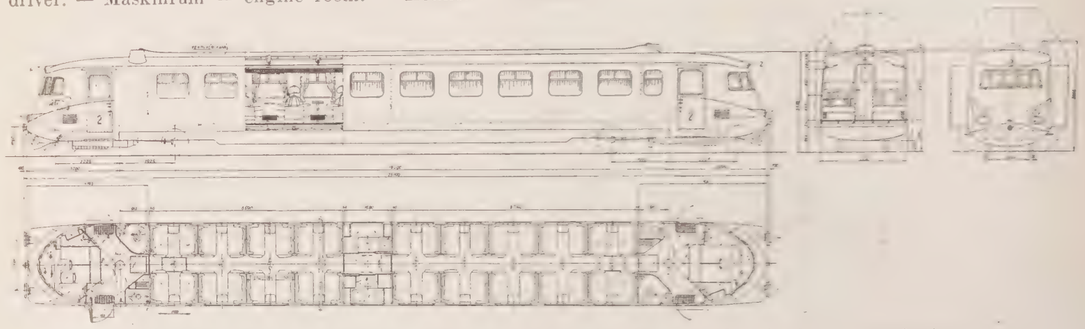


Fig. 56. — Fast railcar with *Sousedik* electro-mechanical transmission, *Czechoslovak State Railways*.

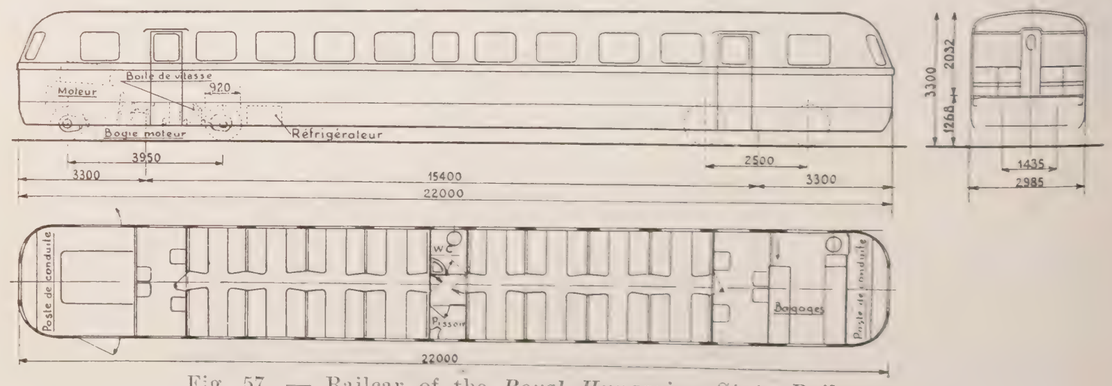


Fig. 57. — Railcar of the *Royal Hungarian State Railways*.

— Passenger compartments: single class, 72 seats, including 8 tip-up seats.
— Luggage compartment: 5.50 m² (59 sq. ft.).
— Heating: by engine cooling water.
— Interior lighting: tubular lamps, 800 W. in all.
— Kind of transmission: mechanical.
— Engine: Ganz-Jendrassik 200-H.P. at 1 500 r.p.m. 6-cylinder diesel. Bore, 6 11/16". Stroke, 8 11 16".
— Starting: by battery.
— Gearbox: Ganz, 5 speeds.
— Braking: 1. Knorr compressed-air automatic. 2. Screw (hand) brakes.
— Accumulator battery: lead, 320 amp./h.
— Total weight empty, in working order: 27 tons (metr).
— Total weight loaded: 35 tons (metr.).
— Maximum power developed by engine in service: 275 H.P.
— Railcar can be driven in both directions (2 driver's compartments).
— Maximum speed: 120 km. (75 miles) p. h.
— Acceleration (calculated): 115 km. (71.5 miles) per hour in 373 seconds.
— Stopping distance (calculated): from 120 km. (75 miles) an hour in 700 m. (3 000') on the level. From 90 km. (56 miles) an hour in 405 m. (1 330') on the level.

Note. — Moteur = engine. — Boîte de vitesse = gearbox. — Bogie moteur = motor bogie. — Réfrigérateur = cooler. — Poste de conduite = driver's stand. — Bagages = luggage.

are exclusively used for carrying passengers. In view of the long distances to be covered, a dining room with 29 seats together with a kitchen and pantry, are provided in the other end car (fig. 48). The prime mover is a 1 300-h.p. M.A.N. supercharged diesel engine. The current produced by the main generator is conveyed to the four driving motors which are distributed in pairs over the inner bogies of the two end vehicles. The main power unit after the automatic coupling has been disconnected may be separated from the rest of the train, and move under its own power. This will provide great facility when dealing with long trains in the sheds, since the engine car alone requires to be kept under cover, while the remainder of the train can be left in the open. An auxiliary power plant of 150 h. p. is also provided in the engine car, for all the auxiliary services (air compressors, ventilators, lighting, etc.) and will drive the train at a moderate speed, in case of breakdown of the main power plant.

A synopsis of the high-speed railcars of the *Deutsche Reichsbahn* will appear in the July 1937 number of this *Bulletin.*

Apart from the high-speed railcars referred to above, and intended for a maximum speed of 160 km. (100 miles) an hour, there are also several twin and triple railcars for fast services in the Ruhr district and on certain main lines; these are equipped with 2 engines of 400 h. p. each and were designed for a maximum speed of 120 km. (75 miles) an hour. As a novel type, furthermore, a fair number of eight-wheeled railcars with 360-h. p. engines and hydraulic transmission have been supplied recently (figs. 49 and 50). The M.A.N. type W. 6 V. 22/30 diesel engine carried on one of the bogies (cf. table II), is a slow running engine (900 r.p.m.). This engine was chosen experimentally, because lower maintenance costs were expected, owing to its robust design. The greater engine weight (8.8 kgr. = 19.4 lb. par h. p.) has been taken into account when designing the remaining part (vehicle), so as to compensate this heavy weight by suitable lightening, thanks to which the railcar in working order will only weigh 37 tons.

Special diesel-hydraulic observation railcars have been introduced for journeys through picturesque country, the first designs of which are shown in figures 51 and 52. Noteworthy features of these vehicles are the large side windows, the cambered windows in the roof, and a large opening in the roof, fitted with roller shutters worked by an auxiliary motor.

Fitting this roller shutter proved a particularly difficult problem. Indeed, although the vehicle has to be of the lightest possible design, and it was possible to cross-brace the body only at the centre and ends of the coach, the question was to obtain sufficient rigidity of the body which had, furthermore, to carry two power units and allow of speeds up to 120 km. (75 miles) being reached.

The railcar has two 180-h. p. horizontal engines built by the *Deutsche Werke,* at Kiel, and a *Heidenheim-Voith* double hydraulic transmission. Each of these transmissions consists of 2 torque converters and 2 couplers. Up to 60 km, (37.3 miles) an hour, both converters are worked; beyond this speed up to 85 km. (52.8 miles) an hour one of the couplers, and above this speed up to 120 km. (75 miles) an hour, the second coupler is brought into use. For further particulars see *Die Reichsbahn,* 8th July 1936, page 562.

In *Denmark* four high-speed triple railcars have been in service since the middle of 1935; these cars are illustrated in the report of Messrs. Dumas and Lévy, on page 1008 of this *Bulletin,* August 1935 number. Each end vehicle of these motor trains is equipped with 2 *Frichs* diesel engines side by side, each of 250 h. p., nominal power.

A new quadruple-unit design with

similar arrangement of the engines in the two end cars is in course of construction. This motor train (fig. 53) comprises 6 bogies in all and is divisible in the centre. Consequently the bogies Nos. 1, 3, 4 and 6 are ordinary separate bogies and Nos. 2 and 5 articulated (Jakobs) bogies. One of the end coaches contains, in addition to 40 second-class seats, a dining compartment with 16 seats, and a small electric kitchen. The other end coach, in place of the dining compartment, has a large luggage compartment, but otherwise has the same layout as the other end vehicle. One of the centre coaches offers accomodation for 76 second-class passengers, and the other for 42 first-class and 8 second-class passengers.

A new railcar of the *Polish State Rys.* is shown in figure 54; it is equipped with a Saurer engine and Mylius-Voith transmission.

The *Swiss Federal Rys.* possess modern railcars, the external shape of which recalls the *Austro-Daimler* railcars of the *Austrian Federal Rys.* described in the earlier report. They were built by the Swiss Locomotive and Engineering Company, Winterthur (fig. 55). These railcars have a 290-H. P. Sulzer engine driving two bogie axles through a 5-speed gear, reverse gear and cardan shafts. The various working speeds are 28, 49, 70, 96 and 124 km. (17.4, 30.4, 43.5, 59.6 and 77 miles) an hour. The tare weight of the vehicle is 32 tons.

The *Czechoslovak State Rys.* also own similar fast railcars (fig. 56). These cars, designed for a maximum speed of 130 km. (80.8 miles) an hour, have a 165-H.P. petrol engine with *Sousedik* electro-mechanical transmission (cf. Chapter IV-*c*). The railcars have a tare weight of 36 tons.

Finally, figure 57 shows the railcars of the *Hungarian State Rys.*, with a 220-H. P. Ganz-Jendrassik engine and *Ganz* 5-speed mechanical gearbox.

Further particulars are given in the drawing, figure 57.

* * *

IX. — Test methods and measuring equipment.

I. — Tests of railcars.

A detailed description was given in the August 1935, *Bulletin of the Railway Congress,* pp. 888 to 894) on the methods more generally used for determining the characteristics of self-propelled railcars with special reference to the measuring methods used on the *French State Rys.* The *Reichsbahn* test methods which in their general principles tally with those of the French Railways, have been improved since railcars ordered in 1934-35 were supplied and put into service.

The method evolved by the Locomotive Testing Section, Berlin-Grunewald, in conjunction with the Headquarters Offices of the Reichsbahn is as follows :

1. Test bench trials for recording the *characteristic curves of the engine;*

2. *Starting tests,* for determining the accelerations of the railcar;

3. *Coasting* and *hauling* trials, to determine the running resistance;

4. Continuous runs at working speed for recording the power characteristic of the railcar (excess power, i.e. excess tractive effort);

5. Determination of the fuel consumption *during the starting period* (item 2) and in continuous running (item 4);

6. *Calculations :*

(*a*) Determination of transmission coefficient and the coefficient of use from the values of item 4;

(*b*) Establishment of the s-V. diagram (accelerative effort per ton hauled in relation to the vehicle speed) from the values in items 3 and 4.

(1) *Characteristic curves of the engine.*

These characteristic curves indicate the torque (*Md*) in kilogrammetres and the horse-power (*Ne*) at the driving shaft, both in terms of the engine speed (r.p.m.). Furthermore, they show the fuel consumption (B), in grammes per H.P./hour, in terms of the power corresponding to the nominal r.p.m. For establishing these characteristic curves, the engine is lifted out of the railcar, and coupled to hydraulic brakes on a specially designed test bench. This method is that used on most of the Railways. In *Austria,* use is made to some extent of an electric brake with hydraulic resistance.

The Deutsche Reichsbahn is now designing measuring equipment for recording the power of the engine in service in the railcar, during trial runs. The equipment described as a « torsion meter » operates on the « vibrating wire » principle, under the action of the torque which drives the crank shaft, with which variations in the mechanical stresses are produced in the wire held tight between two clamps.

The variation in the vibration period of the wire is transmitted to an electric receiver and tuned against a standard wire. The variation in length of the latter gives the value of the torque transmitted. This test method is however still in the development stage.

Preliminary remarks on the trial runs. — The testing technique as developed by the Reichsbahn gives all the necessary characteristics for comparing railcar designs by runs *on the level.* In order to repeat all the practical working conditions, all runs are carried out both with the railcar by itself, and with a trailer, also with railcar empty and loaded. The added load in the latter case is equivalent to the number of seats × 80 kgr. less an allowance for the staff present on the run and the measuring instruments carried. For luggage and mail, a load of 250 kgr. per square metre of the space available for such purposes is added.

(2) *Accelerations of the railcar.*

In order to determine the rates of acceleration, a record of the starts is made with the time-distance recorder described in the August 1935 *Bulletin,* p. 934.

In order to eliminate the effect of the wind, the tests are generally repeated 6 times in both directions. The results will therefore be the average values, relating to runs on the level, in calm weather, or at most with light wind. The mean acceleration over the entire run is found by planimetry. A diagram giving the speeds, accelerations and distance run, in respect of a diesel-electric railcar is reproduced in figure 58.

(3) *Running resistance (bearing friction, rolling and air resistances).*

In order to determine experimentally the running resistance, the railcar is run at its maximum speed on a straight level track through a wood, the power is then cut off and the car allowed to coast. Railcars having mechanical or hydraulic transmission are pushed by a steam locomotive, whereas railcars with electric transmission are brought up to speed under their own power. The difference in the way the units are brought up to speed is due to the fact that with mechanical gears the reversing gear may not be put in the neutral position, and with hydraulic transmission the measurement would be inaccurate owing to the too long time taken to empty the transmission. The resistance curves are deduced from the retardation curves recorded by the time-distance recorder, allowance being made for the mass of the vehicle. The influence of the revolving masses on the running resistance are taken into account by applying an appropriated coefficient to the values measured experimentally. In order to ascertain the running resistance with sufficient accuracy at low speeds, running tests are also

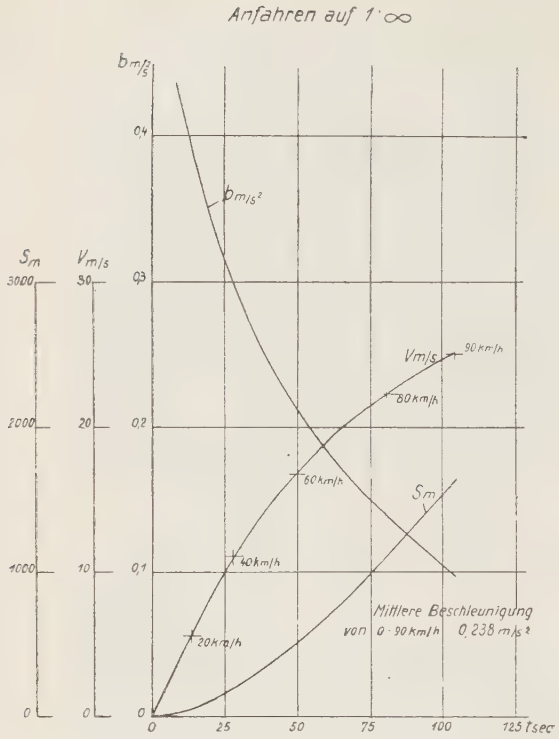


Fig. 58. — Diagram of speeds and accelerations of, and distances covered by, a diesel-electric railcar.

Note. — Anfahren auf 1 : ∞ . — Starting on level track. — Mittlere Beschleunigungen von 0-90 *km*, etc. = mean acceleration from 0 to 56 miles an hour : 0.238 m. (0.78') per sec per sec. — t. sec. = time, in seconds. — b m/s² = acceleration in metres per sec. per sec.

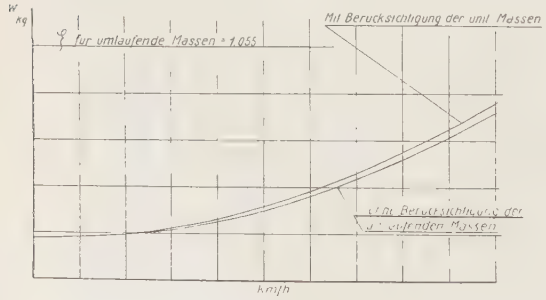


Fig. 59. — Running resistance on the level.

Note. — Für umlaufende Massen = for revolving masses. — Mit Berücksichtigung... = taking the revolving masses into account. — Ohne Berücksichtigung... = without taking the revolving masses into account.

made in which a small shunting locomotive provided with dynamometer draw hook is made to haul the railcar. The curves obtained (fig. 59) agree approximately with the equation :

$$W = w_1 . G + 0.5\ c_w . F \left(\frac{V}{10}\right)^2, \text{ in kgr.,}$$

wherein

w_1 = Specific rolling and axle bearing resistance, in kgr./ton;

G = Vehicle weight in kgr.;

c_w = Additional air resistance deduced from wind tunnel tests, or from the formula by substituting the coasting and haulage tests for the values found for w_1 and W;

F = Cross sectional area of vehicle, in square metres;

V = Working speed, in km./hour.

The *French* and *Czechoslovak* Railways proceed quite differently, they determine the running resistance on downhill gradients of known slope.

(4) *Power characteristic of the railcar (excess power, i.e. excess tractive effort).*

By « excess power » is meant that portion of the capacity which is available for climbing gradients, for meeting abnormal air resistance, or for hauling trailers. This excess corresponds to the difference between the maximum power developed by the engine while the railcar is running when being braked, and that at reduced load, corresponding to running on the level, unbraked. The determination of the excess capacity, hence the excess tractive effort, forms the basis of the *s*—V diagram used when drawing up the timetables.

The test method consists in checking the railcar by suitably applying the hand brake, the engine working under full load (maximum injection), the railcar running at the desired speed until the working speed is obtained. The test is carried out with all speeds on the gear

box and at various vehicle speeds. With electric transmissions, the capacity is determined by electrical measurements. With mechanical or hydraulic transmissions, a hydraulic dynamometer box is interposed between the railcar and the trailer, in place of the screw coupling, the drawbar pull being then measured with the trailer having the brakes on. The excess tractive effort is the difference between the tractive pull shown by the dynamometer box and the running resistance of the unbraked trailer.

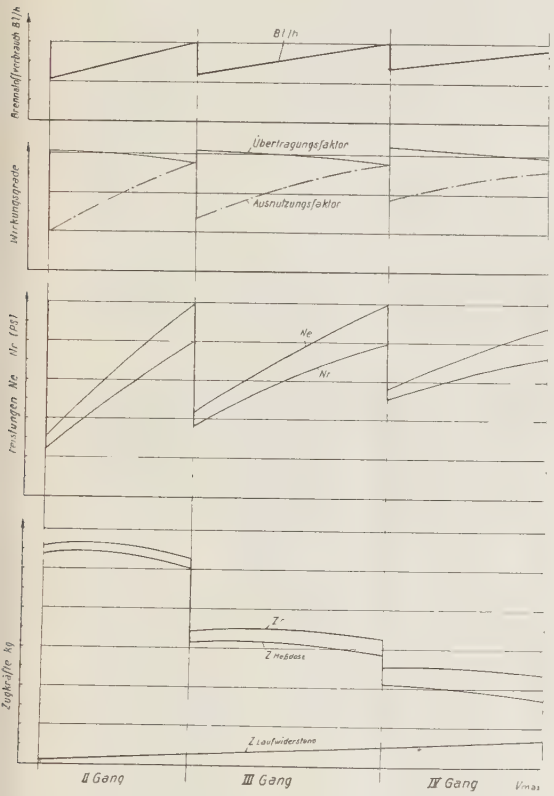


Fig. 60. — Running at working speed on the level.

Note. — Zugkräfte... = tractive efforts, in kgr. — Leistungen Ne ÷ Nr (*PS*) = power developed by the engine, and at the wheel tread (H. P.). — Wirkungsgrade = efficiencies. — Brennstoffe... = fuel consumption, in litres per hour. — Übertragungsfaktor = transmission coefficient. — Ausnutzungsfaktor = coefficient of use. — Messdose = dynamometer box. — Laufwiderstand = running resistance.

Figure 60 is a curve calculated for a diesel railcar with mechanical transmission.

(5) *Fuel consumption.*

In order to determine the fuel consumption, a calibrated fuel tank is used, connected to the engine feed pipe by a three-way cock. The fuel consumption is determined in litres per minute during the starting period, and in litres per hour while running at working speed. The values obtained during the latter run are converted into grammes per horse-power/hour.

(6) *Transmission coefficient and coefficient of use.*

The transmission coefficient is the ratio of the power (N*r*) at the wheel tread to the power (N_1) available at the input side of the transmissions. N*r* may be calculated from the formula

$$N_r = Z_r \cdot \frac{V}{270},$$

by means of the tractive effort (Z*r*) determined as stated in (4). The value of the power N_1 is given by the test bench power curve N*e* after deducting the power required by the auxiliaries (fans, lighting dynamo, air compressor).

The coefficient of use of the plant is given by the ratio of the power (N*r*) at the wheel tread to the available engine capacity (N*e*).

(6) *s V diagrams.*

These are prepared in order to :

(*a*) determine the minimum time spent on the run, to which end the nominal power, without excess capacity, is taken, and the weight of the railcar in running order, with stores, but not loaded, the vehicle running alone;

(*b*) determine the time to be spent on the run as to be shown in the timetables by taking the continuously available power, i.e. the nominal power, reduced by

15 % and weight of the railcar in working order, running loaded (with useful load and stores).

The gradient climbing ability, i.e. the slope of the steepest gradient corresponding to each working speed is deduced from the formula

$$s = \frac{Z - W}{G} \, ^0/_{00}.$$

When dealing with electric transmissions — owing to the heating conditions of the electrical equipment — the hourly tractive effort consistent with the hourly current intensity will limit the values of the *s*—V diagram. The maximum tractive effort Z*r* can be fully used only momentarily, during the starting period.

II. — Measuring equipment.

(a) *Germany.*

The *Deutsche Reichsbahn* is at present building a special dynamometer car containing all the necessary apparatus for testing rail motor cars. This dynamometer car is equipped with a tractive-effort recorder with disk planimeter. The vehicle speed, time and distance covered are recorded on the same band.

Coupling sockets for 32 measuring circuits are fitted to the end walls of the dynamometer car, for measuring the current strength and voltage, for recording the number of revolutions per minute, cooling water temperatures, battery charging values, and position of the control handle. All records are plotted on the distance covered. For temperature measurements, six-colour recording instruments are available. A graph obtained during a test with the dynamometer car is shown in fig. 61.

(b) *Hungary.*

Reference should be made to an intetesting test method due to Messrs. *Ganz & Co.*, Budapest, to determine the efficiency of the gear boxes in diesel-mechanical plant carried on motor bogies. Two perfectly identical motor bogies are placed side by side with the wheels clear of the ground so as to allow the axles to revolve freely. One axle of the first bogie is connected with the corresponding axle of the second by means of a shaft with flexible couplings. In place of the diesel engine a D.C. motor is mounted, which drives the corresponding gear through a cardan shaft. The power developed thus passes via the mechanical transmission gear to the axles of the first bogie, via the coupled shaft, to the axles of the second bogie, and thence via the second gear box to a generator mounted in the place of the second diesel engine. The current produced by the generator is returned to the driving motor so that the current fed into the test unit has merely to cover the electrical and mechanical losses. As the motor and generator losses can be ascertained quickly and as the proportion of the losses due to each bogie can be determined mathematically, the mechanical efficiency of the transmissions (gear boxes) can be easily found.

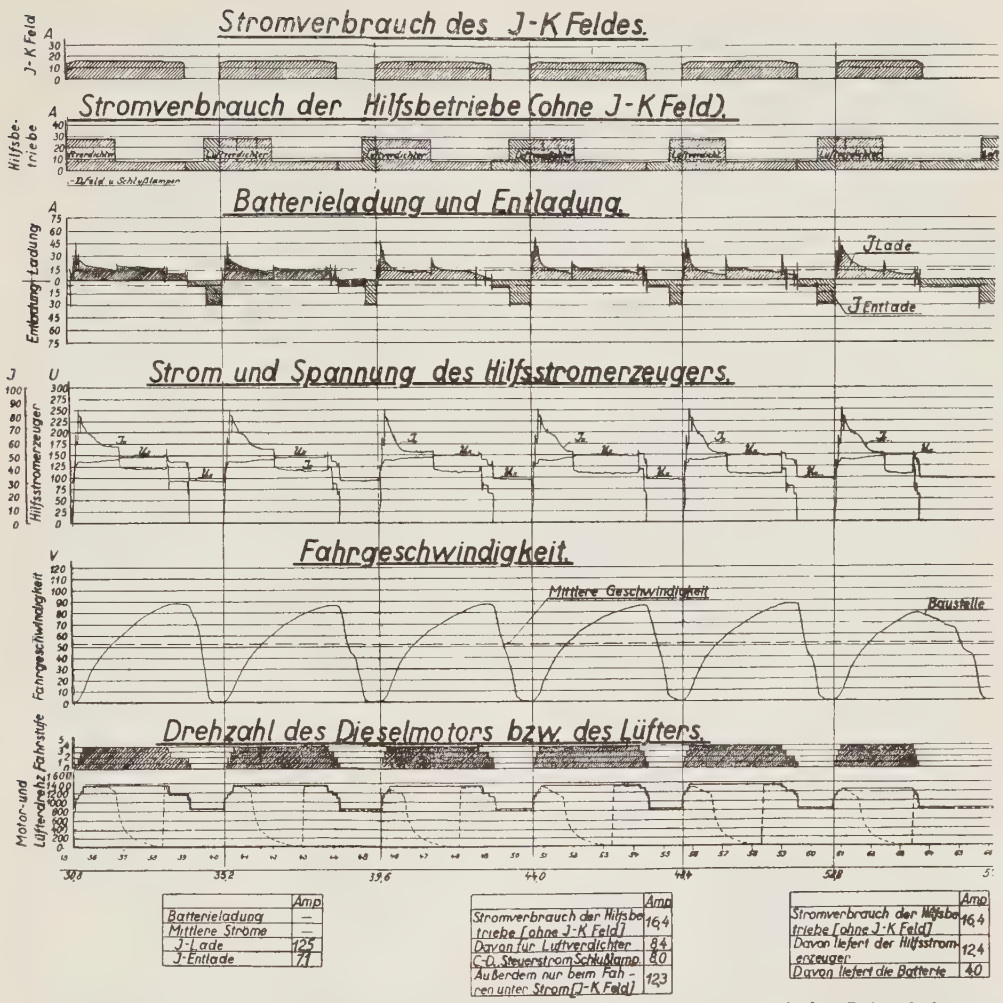
The advantage of this test method is that electric units, whose individual losses are readily determined, are used. The reduction of the speed (r.p.m.) due to the gearbox in the first bogie is compensated in the other bogie by the arrangement being reversed therein, the generator thus revolving at the same speed as the electric motor. By means of such equipment, therefore, the losses and efficiencies of diesel-mechanical driving bogies can be determined satisfactorily and independently of road tests, provided the negligible effect of the stresses on the sides of the gear teeth when reversing are ignored.

* * *

X. — First cost and working expenses.

a) First cost.

The cost of building railcars of the various designs in use and operating them cannot be compared directly, since



	Amp.
Batterieladung	—
Mittlere Ströme	—
J-Lade	125
J-Entlade	7,1

	Amp.
Stromverbrauch der Hilfsbetriebe (ohne J-K Feld)	16,4
Davon für Luftverdichter	8,4
C.-G. Steuerstrom Schutzlampe	8,0
Außerdem nur beim Fahren unter Strom (J-K Feld)	12,3

	Amp.
Stromverbrauch der Hilfsbetriebe (ohne J-K Feld)	16,4
Davon liefert der Hilfsstromerzeuger	12,4
Davon liefert die Batterie	4,0

Fig. 61. — Diagram recorded by means of the dynamometer car of the *Reichsbahn*.

—	Amp.
Battery charging	...
Mean currents	...
Charging intensity	125
Discharge intensity	7.1

—	Amp.
Current consumption by auxiliary services (not including I-K field)	16.4
Including consumption by air-compressor	8.4
Working current	8.0
In addition, when running under current only (I-K field).	12.3

	Amp.
Current consumption by auxiliary services (without I-K field)	16 4
Including current supplied by auxiliary generator . . .	12.4
Supplied by battery	4.0

Explanation of German terms:

Stromverbrauch des I-K feldes = current consumption of I-K field. — Stromverbrauch der Hilfsbetriebe (ohne I-K Feld) = current consumption of auxiliary services (excluding I-K field). — Batterieladung... = charge and discharge of battery. — Strom und Spannung... = current intensity and voltage of auxiliary generator. — Fahrgeschwindigkeit = vehicle speed. — Drehzahl... = r. p. m. of diesel engine and fan. — Fahrstufe = speed. — Entladung (Ladung) = discharge (charge). — Hilfsbetriebe = auxiliary services. — I-Lade (Entlade) = charging (discharge) intensity. — Mittlere Geschwindigkeit = Mean speed. — Baustelle = speed restriction owing to track work in progress.

the conditions in the different countries with respect to raw materials and wages are quite different The cost of production depends also upon whether only a few railcars of a given design are ordered, or large numbers are built on mass-production lines. The conditions obtaining in the particular case of a few railways will, therefore, be described herafter.

1. *Germany.*

As the construction of railcars in Germany is still in the development stage, the various designs have been ordered only in small numbers. hence the first cost is relatively high. An endeavour is made to standardise the various designs as far as possible, so that the standard types adopted may be ordered in larger numbers. It should thus be possible to reduce the first cost. For example, it is proposed to build the bodies of the 8-wheeled railcars of 200, 300, 400 and 600 H. P. and their trailers equipped for distant control, according to standard drawings.

The bogies likewise are to be standardised in such a way that in future there will only be a small number of types, which will carry engines of approximately the same power, but built by different makers, and which will be interchangeable, if required.

The entire internal arrangement will in future likewise be standardised.

The engines and power transmissions are still in the development stage and the prices are therefore still heavily affected by the research costs.

Light construction and the use of welding in the place of riveting are also factors influencing the final costs. Light construction, if related to the kilogramme of railcar weight, is in any case comparatively higher; frequently, however, the total cost of the railcar may not be increased given equal power. For instance, a good welded body and bogie construction, with special regard to the dynamic stresses set up in vehicle, is invariably dearer than rivetted construction, owing to the more extensive preparation work and the higher wages of welders. By means of appropriate design, however, made possible only by welding, the weight may frequently be lowered to such an extent that the total cost will remain about the same. A similar result is obtained when high-grade structural steel (St. 52) is used in the place of ordinary St. 37 steel. In this connection it should be borne in mind that such new designs also incorporate improved riding qualities, apart from the lower weight resulting in a reduction of the operating costs, together with greater safety against accidents, and that lower maintenance costs may be expected (see in this connection Chapter VI, § *b*).

As regards interior decoration, a weight saving means a higher cost only when more expensive materials are used, for example light alloys. As the same time some extra expenditure to get the weight down is almost invariably justified in connection with railcars.

2. *Denmark.*

In Denmark the diesel engines, transmissions, and the greater part of the actual railcar body have been standardised only in the most recent designs. Whether this will reduce the cost price cannot be said as yet.

3. *Czechoslovakia.*

In *Czechoslovakia* a reduction of the production costs of railcars is not considered possible; on the contrary, owing to the greater requirements of the passengers as regards comfort, a higher cost price is expected.

In future, railcars are to be acquired only of those designs which have proved most satisfactory. Although these do not have many components in common, a reduction in cost price of approximately 10 % has nevertheless been possible by standardising the railcars.

An appreciable influence upon the

total cost of the railcars has therefore arisen from the makers' expenditure on research work (designing), to which must still be added the cost of maintenance of the diesel engines during the guarantee period. In Czechoslovakia, railcars of ultra-light construction are not in existence, and light materials or expensive building methods with a view to ensuring lighter construction have not been applied. By resorting to welding instead of riveting, no reduction in the purchase price of railcars has been secured.

4. *Hungary.*

In *Hungary* the numbers of types of railcars and their components have been reduced as far as possible, and only three engine designs, three coach (body) designs, and two types of transmission are used.

The motor bogies and, in the various railcar designs, the interior fitting out, engines, transmissions, reverse gear and other mechanical compenents have been standardised. The cost price has been reduced in this way.

Light-metal construction has not been used, but minor weight saving have been effected by using pressings of high tensile steel, as also small fittings of light alloy. The change over from rivetting to welding has not affected the cost price.

b) **Operating costs.**

The particulars furnished by the various railways as to the costs of railcar operation do not allow of any comparison being made between them. On the one hand, the conditions in individual countries (wages, general economic conditions, cost of fuel — according to whether produced at home, or imported and subject to more or less high customs duties) differ entirely, while on the other hand, the statistics from which the working costs are computed are not drawn up in the same way. By way of example, a subdivision in the operating costs (percentage) is given below, as obtained in Germany from provisional returns :

1. Capital charges (interest, depreciation, etc.)	13.7 %
2. Fuel	15.0 %
3. Operating materials (sundry stores)	3.8 %
4. Supervisory staff	1.9 %
5. Railcar staff	29.3 %
6. Labourers	5.1 %
7. Workmen	3.8 %
8. Actual railcar maintenance costs	27.4 %
Total operating costs	100.0 %

In this table the capital charges (it. 1) have been calculated as follows :

Interest on invested capital = 4.5 % of purchase cost.

Amortisation = 2 % of purchase cost.

Added to the whole the interest and amortisation (4.5 % + 2 %) on capital spent on the whole of the maintenance plant.

The operating costs are appropriated in a similar way in *Rumania* and for a few railcar designs in *Jugoslavia* and *Hungary*, whereas the operating costs in other countries appear to be determined according to other view points, and consequently cannot be compared with the results obtained in Germany. In order to get comparable values, it would be desirable on a future occasion to submit to the railways a new questionnaire with specimen forms for completion showing the method of calculation.

As to the real life of the railcars and their main components until they are scrapped, accurate particulars cannot as yet be furnished, since railcars have only been in service for a few years. The particulars as to the probable life of the body portion of the railcars vary between 15 and 25 years, and of the engines and the mechanical plant, between 8 and 12 years. It is to be recommended that, after a few years' experience in this matter, the question of the life of railcars be raised again.

c) Operating results.

The particulars supplied by the different Railways on the daily mileage run by their railcars vary between wide limits, since on some Systems a certain number of spare cars is maintained and this reduces the daily performance based on the number of cars in service. On the *Deutsche Reichsbahn*, for example, the 4-wheeled branch-line railcars run approximately 275 km. (171 miles) per day of use. If the spare cars be included the performance is 220 km. (118 miles) per calendar day. The 8-wheeled branch-line railcars cover 350 km. (218 miles) whereas the main-line 8-wheeled railcars covers 425 km. (265 miles) per day of utilisation. Only those railcar types have been considered here, of which there are a fair number in use. With the high-speed railcars, the distance covered on the average exceeds 1 000 km. (620 miles). But if the reserve vehicles are taken into account, their number being as yet comparatively high owing to the small number of long-distance services, the average distance covered is reduced to 550 km. (345 miles) per railcar per calendar day.

Similarly the number of days at work and those laid up for maintenance differ widely from one Railway to another, more especially as the services in the main are still of an experimental nature and the railcars are not used in large numbers.

The mileages covered between two general overhauls also vary according to the methods of using the stock. For the time being, repairs to the internal-combustion engine still govern the general overhaul interval on most Railways. Even now a distance of 150 000 km. (93 000 miles) is covered between general overhauls in many cases.

How far the daily mileage is covered by railcars working alone or with trailers, or by several railcars formed into a train (multiple units) cannot be stated owing to lack of data. It is desirable that at a later date the Railway Administrations should be asked to complete a more precise questionnaire with a specimen form showing clearly how the calculations should be made, so that a clear opinion on the efficiency of railcars may be formed.

[621. 43]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

13th SESSION (PARIS, 1937).

QUESTION IV.

Evolution of the rail motor car
as regards its construction, and special investigation into the transmission and brake questions.

Comparative methods of testing railcars.

Detailed investigation into the costs of railcars and the methods of reducing them.

REPORT

(Belgium and Colony, Spain, France and Colonies, Great Britain, Dominions and Colonies, Italy, Luxemburg, Netherlands and Colonies, Portugal).

by L. DUMAS,

Ingénieur en chef adjoint du Matériel et de la Traction, French Nord Railway,

and J. LEVY,

Chef adjoint du service du Matériel et de la Traction, French State Railways.

FOREWORD.

Evolution of the rail motor car as regards its construction (1935-1937)

At the Enlarged Meeting of the Permanent Commission of the International Railway Congress Association, held in July 1935 (*), we presented a report on rail motor cars from the constructional point of view, in which we described the main types then used in Europe ; Mr. WANAMAKER also described at the same time the principal types in the British Empire and the United States of America (**).

We have been appointed reporters for the Paris 1937 Congress on the question of the evolution of the rail motor car from the constructional point of view, in Western Europe and the British Empire.

We propose to limit our investigation to the progress made during the last two years, referring when necessary to the 1935 reports for descriptions of rolling stock in service or under construction at that time.

Our report will be divided into the following sections :

(*) See *Bulletin of the Railway Congress*, August 1935.
(**) See *Bulletin of the Railway Congress*, January and June 1935.

Chapter I. — General.

Chapter II. — Diesel engines.

Chapter III. — Transmissions.

Chapter IV. — Brakes and running gear.

Chapter V. — Safety and comfort.

Chapter VI. — Comparative tests.

Chapter VII. — Maintenance methods.

Chapter VIII. — Cost prices.

Appendix I. — Rail motor cars in the various countries.

Appendix II. — Leading dimensions and constructional details of the more important engines used by the various Railways.

* * *

In this report we have used the word « autorails » (railcars) throughout instead of « automotrices », (motor coaches), to describe rail vehicles equipped with internal-combustion or steam engines.

We think that it is desirable to avoid any confusion with the « automotrices électriques » (electric motor coaches) which, although not covered by our report, are mentioned therein because they have certain interesting points in common with railcars ; electric motor coaches now incorporate features drawn from the most recent railcar practice, in Italy, Holland, on the French State and P.O.-Midi, for example.

We will also use the expression twin-unit, triplet, quadruplet railcars,... multiple-unit or rail motor trains, to describe a rake of a number of railcars with internal-combustion or steam engines, based on the new technique, from the double railcar up the 17-coach 4 500-H.P. diesel train put into service between Chicago and Los Angeles.

* * *

CHAPTER I.

General.

Rail motor cars built during the last few years have naturally the acceleration, braking, reversibility, and low running costs which have done so much to make the first units being appreciated and developed.

Two new qualities seem to mark the evolution of rail motor car technique in the last two years : increase in power and increase in capacity.

Owing to the higher power, all Railways are increasing the average speed and the maximum speed of their railcars, even on branch lines. More and more railcars are now taking gradients at the speed at which they run down them. The additional track maintenance and repair costs are accepted when necessary. From the point of view of the design, this tendency has led to the almost general abandonment of the 4-wheeled railcar and the use of the bogie railcar.

Owing to the increased capacity that may be obtained, either by lengthening the railcar body, by building multiple-units, or by hauling trailers, most of the Railways are replacing trains in regular services by railcars. These are laid out to suit the requirements : kitchen or buffet for long-distance trains, mail compartments in railcars replacing trains carrying mail, customs service compartments in international services, standard couplings when the railcar has to haul an ordinary fast goods wagon.

Some years ago the railcar was still feeling its way and was most of the time confined to additional or connecting services on lines of average or small importance.

Today the rail car has proved its capabilities and shown itself worthy of confidence ; it is now working services over the most important lines of

the Railways, and being more and more called upon to replace, not only stopping trains on branch lines, but even express trains on main lines.

Such confidence in the railcar is justified, as there have not been more incidents on the main lines than with steam trains ; the cost per kilometre run is about half that of the corresponding train (which retains the advantage of a much greater number of seats). Finally, the rail motor car has found favour with the public.

* * *

The most up to date railcars can be classified as follows, according to the service worked :

A. — *Railcars for ultra high-speed services.*

These railcars equipped for through high speed services are able to run at 120 km. (75 miles) an hour as a minimum, and usually at 140 km. (87 miles) ; they are in some cases able to replace either number for number or in the ratio of 2 to 1, fast steam trains not fully used (figs. 1 to 6).

Fig. 1. — Baume & Marpent triple railcar with two 365-h.p. *Carels-Ganz* diesel engines (Belgian National Railways Company).

B. — *Railcars for other services.*

These railcars can be divided into three classes : 1. Railcars not hauling trailers, and which cannot be run as twins or be coupled together. These railcars are as a rule very light, very cheap to run and can cover shuttle services at high speed, with high rates of acceleration (figs. 7 to 10).

2. Railcars which can be run as twins or be coupled together. These railcars are as a rule run as twin units, or units coupled together at peak hours to provide larger carrying capacity ; they have the marked advantage of not necessitating two separate train workings, hence less line occupation. They are somewhat dearer and heavier (frame, coupling and buffing gear) than the previous railcars.

Fig. 2. — Triple railcars of the Netherlands Railways.

Fig. 3. — FIAT triple railcăr, with two 450-H.P. *Fiat* engines (Italian State Rys.).

3. Rail motor cars which can run with trailers specially designed or not. These railcars are the heaviest ones and they must be of ample power ; their chief feature is their great carrying capacity as regards passengers and luggage, and their special equipment for dealing with mail and parcels traffic. These railcars offer the operating department great facilities for the replacement of steam trains.

The following table gives for the

different railways the rail motor cars on order or under construction on the 1st October 1936, grouped according to the different classes, and consequently shows the tendency on each Railway.

Railcars on order or being built at the 1st October 1936.

—	A. Fast railcars.	B. Other railcars.		
		Light railcars that can only be run as single units.	Railcars that can be used coupled together or as twin units, but cannot haul trailers.	Railcars which can haul trailers, of special design or not.
England.				
L.M.S.	1	...	...	...
France.				
Alsace-Lorraine. . . .	...	...	7	...
Est	3	4	13	11
State	15	20	7	8
Nord	4	..	...	17
P.L.M.	6	4	14	6
P.O.-Midi	3	5	...	14
Netherlands.	...	...	8	...
Italy.	9	137	...	...

Fig. 4. — Two Franco-Belge type triple railcars coupled together (French Nord Ry.).

Fig. 5. — BUGATTI triple railcar, with four 200-H.P. engines (French State Rys.).

Fig. 6. — RENAULT triple railcar, with two 500-H.P. engines (French State Rys.).

Fig. 7. — Messrs. Rulot and Ghilain beside a BAUME & MARPENT railcar, with one 320-H.P. GANZ engine (Belgian National Rys. Co.).

Fig. 8. — Nivelles-Sentinel railcar with two 125-h.p. steam engines (Belgian National Rys. Co.).

Fig. 9. — 96-seater Micheline railcar with one 400-h.p. *Panhard* engine (French State Rys.).

Before going into details, we would like to call attention to some problems which are specially holding the attention of the Railways consulted and have not all been finally solved in a definite way so far.

1. — *Short-circuiting.*

On many Railways the railcar wheels and axles should short-circuit the insulated track circuits of the track signals; difficulties have been experienced with

Fig. 10. — BREDA railcar, with two 125-H.P. engines (Italy).

Fig. 11. — 3 DE DIETRICH 320-H.P. railcars coupled together (Alsace-Lorraine Rys.).

Fig. 12. — BERLIET railcar, with two 125-H.P. engines (can be coupled to another railcar) (Paris-Lyon-Méditerranée Rys.).

pneumatic tyres, with elastic tyres, and even lightly loaded pairs of wheels. The problem has been partly solved.

On the other hand, the use of the electro-magnetic brake is apt to cause irregularities in the working of the track circuits.

2. — *Emergency stops.*

The drivers of railcars may be obliged to make emergency stops, either at a level crossing on which some conveyance has broken down, or before reaching permanent way staff who have not got clear when the rail motor car is approaching.

In such cases a system of braking not depending upon the adhesion ought to be available.

Many railways are using for this purpose the electromagnetic brake, in spite of the defects already mentioned, and the damage to the track that it causes ; a really satisfactory system has still to be found.

Fig. 13. — Armstrong 250-h.p. railcar with standard draw and buffing gear (L.N.E.R.).

In addition to the emergency stops, there is also, on some lines, the simple problem of stopping within the signal location intervals, it being necessary, on

Fig. 14. — 260-h.p. A.E.C. railcar with standard draw and buffing gear (G.W.R.).

Fig. 15. — 600-H.P. DECAUVILLE railcar with standard draw and buffing gear (P.L.M., France).

Fig. 16. — 600-H.P. STANDARD railcar with its trailer (French main-line Rys.).

such lines, to limit the speed of the railcars below their possibilities.

3. — *Approach warning at level crossings.*

When on the same line local trains and ultra-fast railcars are run, the problem arises of warning the level crossing keepers, of the class of train approaching, and protect therefore not only the road vehicle but also the railcar against collision.

4. — *Fire protection.*

Experience has shown that the use of heavy oil, contrary to expectation, is not without certain fire risks ; depositits of solid inflammable matter due to the evaporation of the fuel oil can be formed in fact and start a fire. Thanks to the precautions taken, generally based on aviation practice, no railcar fire resulting in a passenger or one of the train men being burnt has been reported by any Railway. In addition powerful fire extinguishers are provided by all railways.

5. — *Other problems.*

We are far from thinking that only relatively clearly defined technical problems such as those which we have just mentioned remain to be solved for the railcar to reach its finality. On the contrary, we consider that there is still considerable progress to be made as regards design, some of which will be indicated, with the hope it will give rise to further investigations.

First of all, we think that 300 to 600-h.p. diesel engines still require to be developed, and especially to be perfected as regards their suitability for long working periods, and their maintenance.

All the Railways need such engines able to cover without interruption 100 000 km. (62 000 miles) between two heavy repairs, and which can be used again quite safely after repairs for a further 100 000 km.

We also think that all the Railways wish as soon as technical progress makes this possible, to locate the engine, transmission and most of their auxiliaries below the floor level, either under the body or between the bogie frames.

The builders, therefore, should endeavour to design engines which take little room vertically, such as horizontal engines which make the railcar clear from one end to the other for passenger or luggage purposes ; these engines, however, must not involve increased maintenance costs, and to be reliable for the working they must be substantially made and easily accessible.

Engine builders, in our opinion, not only with the object of saving weight, but for reasons inherent in the engines themselves should also *increase the working speeds* of the engines. A speed of 1 500 r.p.m. is now current with diesel engines, but we are convinced that this is only a stage in their development, and that shortly railcar engines will run at 2 000 r.p.m., and be as reliable as with 1 500 r.p.m. In addition to a saving on the engine, there would be appreciable savings in the weight and cost of the transmission of whatever type ; progress in engine design is at the root of railcar progress.

Great progress could still be made in the *suspension of the bogies,* so as to have as *little wear* as possible in service. Heavy maintenance costs and an appreciable reduction in comfort are caused by the play set up in the bogies between their guiding surfaces.

In may perhaps become necessary to reduce to zero the play between the guides ; or maybe all rubbing surfaces will have to be eliminated. In any case, it appears that the present design, in which play develops in the guides and is accepted as the normal thing, will have to be abandoned in the near future.

As regards the *body,* we consider that the use of special steels will make it possible to obtain the maximum weight saving compatible with the strength now required from all-steel coach construction. If weldable high-grade steels have been tried successfully in recent years, there is still some progress to be made in using them scientifically so as to distribute the stresses equally throughout the whole of the sections.

Considerable progress is still to be made as regards the *comfort* of the passengers of all classes, especially as regards the elimination of noise, and we consider that railcar builders have great interest in following aviation technique which has already made remarkable progress in this direction.

Finally we would like to call attention quite specially to the question of *curve negotiation* at very high speeds.

It ought to be possible, by constructional methods, by lowering the centre of gravity, if need be by guiding the bogies or using articulated bogies, to facilitate the passage of the vehicles through curves, and the designers should make it a

point of honour to adapt their ultra-high speed railcars to the curves and superelevation on the track rather than ask for heavy expenditure to be made in correcting the location.

* * *

The list of developments still to be made must not be allowed to cover up the importance of the results acquired in a few years by the new technique.

The railcar is already competing with road motor services and air lines. Where ever the railways have retained their secondary lines because they are necessary to work goods traffic, the railcar can be used to meet road competition and overcome it. Wherever the railways can maintain over distances of 200 to 400 km. (124 to 248 miles) average speeds of some 120 km. (75 miles) an hour, competition from aircraft hampered by the distance between the landing grounds and the centres of cities, appears to be impossible.

The railcar also competes with steam and electric traction. In certain countries the Railways have put off the development of their coaches for steam trains (*Netherlands Rys.* and *French Nord* for suburban trains) ; others have postponed the development of certain electrifications (EST) or have limited the zones to be electrified (ITALY), in order to give diesel traction time to show its possibilities.

Further progress will undoubtedly be made during the next few years.

* * *

CHAPTER II.

Diesel engines.

Power and light-weight, economy and endurance, are the main qualities required from railcar engines by the Railways consulted.

In spite of their apparent contradiction, these characteristics well define the position of the railcar engine, between the powerful light aircraft engine which is however too delicate, and the reliable and economical, but too heavy, marine engine.

The object of the builders during the last two years has been to meet this programme, when supplying new engines or improving existing types.

Power and lightness.

The power has been imposed by the needs of the operators who require ever higher average speeds from railcars, and increasing carrying capacity, together with ever increasing comfort.

About 8 to 10 H.P. per ton is required to meet the first part of this programme ; the weight imposed by the second amounts to 40 tons for a loaded single steel-tyred railcar, and 70 tons for a railcar with its trailer. We see, therefore, engines of 300 to 600 H.P. being developed for single-engined railcars, or for some multiple-units, and 150 to 300 H.P. for railcars with two engines.

These are all theoretical indications, as experience shows that as soon as found possible, the builder tends to exceed this limit of 10 H.P. per ton, and to use an engine with excess power, thus obtaining a railcar the maintenance of which is reduced to a minimum, in time and money, and with which the distance between engine overhauls will be increased. [On the FRENCH STATE a Renault railcar with a 500-H.P., engine usually developing only 200 to 300 H.P., has run in five months 110 000 km. (68 350 miles) at the rate of 950 km. (590 miles) per day in service].

This policy, in spite of its interest, cannot always be applied, as the excess power must not be obtained at the expense of the carrying capacity (engine tak-

ing up too much room), of the useful load (too heavy engine), or of simplicity (too low engine speed) requiring a too sturdy transmission).

As the power of the engines increased, the question of weight became increasingly important, on account of both the weight of the engine itself. and its effects on the design (strengthening of the underframe when the engine is carried on the frame—behaviour on the track in case of engines carried on the bogies).

Applying the methods used in aviation, the builders have obtained very satisfactory results ; whereas in 1934 a certain number of engines had a weight of 11 and 15 kgr. (24.25 and 33.1 lb.) per H.P. the heaviest engines built in 1936 weighed between 9 and 10 kgr. (19.8 and 22.4 lb.) per H.P.

Unfortunately, aviation practice cannot be adopted for endurance and economy reasons.

Endurance. — Economy.

Although the builders have tried to make it easier to replace engines, the work still takes some time and is consequently so costly that it should take place at as long intervals as possible.

Then too the overhaul of the engine involves two classes of expenditure : that which has to be incurred whatever the distance covered by the engine, and that which can be considered as proportional to this distance.

Amongst the former are included most of the costs of labour (stripping, cleaning, examination, re-erecting, tuning up and tests); in the second, replacement parts, with a view to having, after the repair, an engine which will be as good as new, and consequently involving the replacement of parts before they have attained their limit of wear.

The cost par railcar-kilometre due to repairs diminishes therefore as the distance between repairs increases, and this is reflected in the results obtained by the Railways who repair their own engines, and the repair contracts made by other Railways with the builders on the basis of a kilometric rate which decreases as the distance covered increases.

If the life of the engine affects the cost, reliability of working and regularity as regards the distance covered make it possible to cover the service with the minimum of failures and with the least capital expenditure on spare engines, or reserve railcars.

In this respect, a methodical investigation into the behaviour of the engines in service and their defects has given very valuable information, and very interesting results were obtained.

* * *

I. — New engines.

a) *Increasing the power.*

Some builders having got the maximum power possible from engines built in 1934-1935 have been obliged to build new powerful engines which are the result either of an entirely new design [Fiat, 450 H.P.—Frichs 500 H.P. (fig. 18)], or the development of an existing type (Renault, 500 H.P. — C.L.M., 500 H.P., which is nothing but the double 250-H.P.).

This latter method however cannot be made general owing to the excessive amount of room the engine then sometimes takes up.

Increasing the bore of the cylinders or lengthening the stroke has resulted in certain new engines, but the increase in power is always small and limited by the wear and tear of the parts [Saurer-B.X.D.S. engine increased from 150 to 160 H.P. by increasing the bore from 130 to 140 mm. (5 1/8″ to 5 1/2″) : Ganz en-

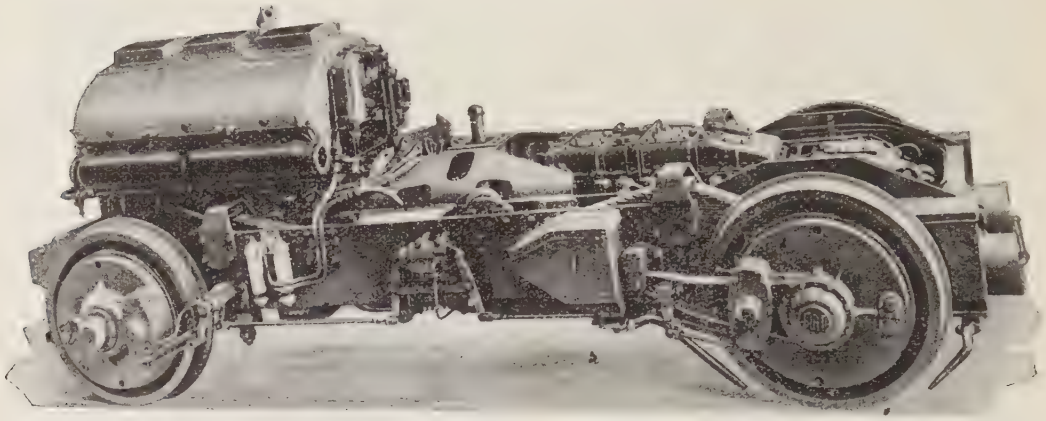


Fig. 17. — Motor bogie, 450-H.P., of FIAT triple railcars (Italian State Rys.).

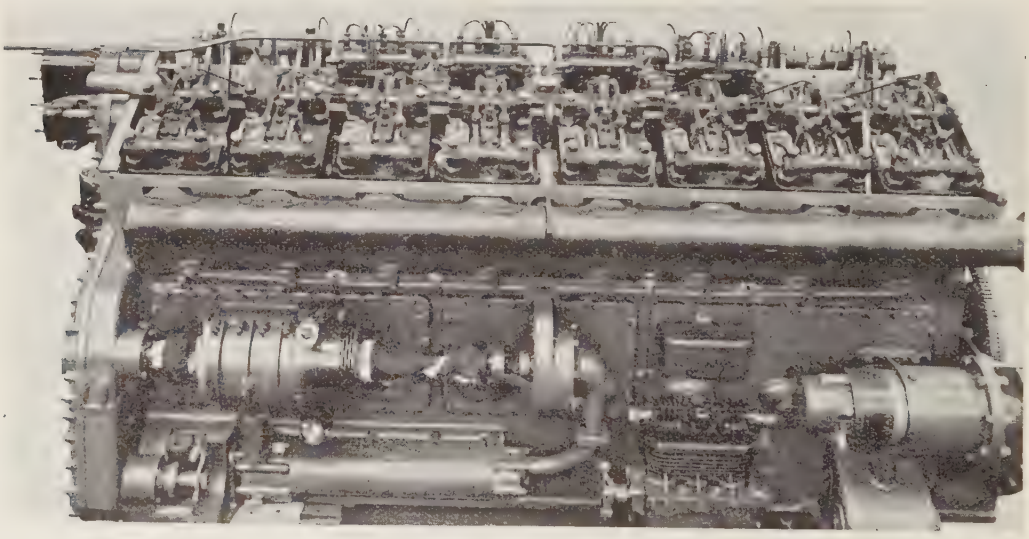


Fig. 18. — RENAULT 500-H.P. diesel engine.

gine (fig. 19) increased from 320 to 365 H.P. by increasing the stroke from 220 to 240 mm. (8 11/16″ to 9 7/16″)].

Finally a very careful investigation into the working of the engine and its tuning up has enabled Renault to obtain 300-H.P. from their 265-H.P. engine by replacing the heads with 2 valves by heads with 4 valves, which provide a better fresh air supply, and a more complete exhaust.

b) *Lightening.*

The demand for lightness has led many builders to raise the speed of rotation of the engines, and in 1936 nearly all en-

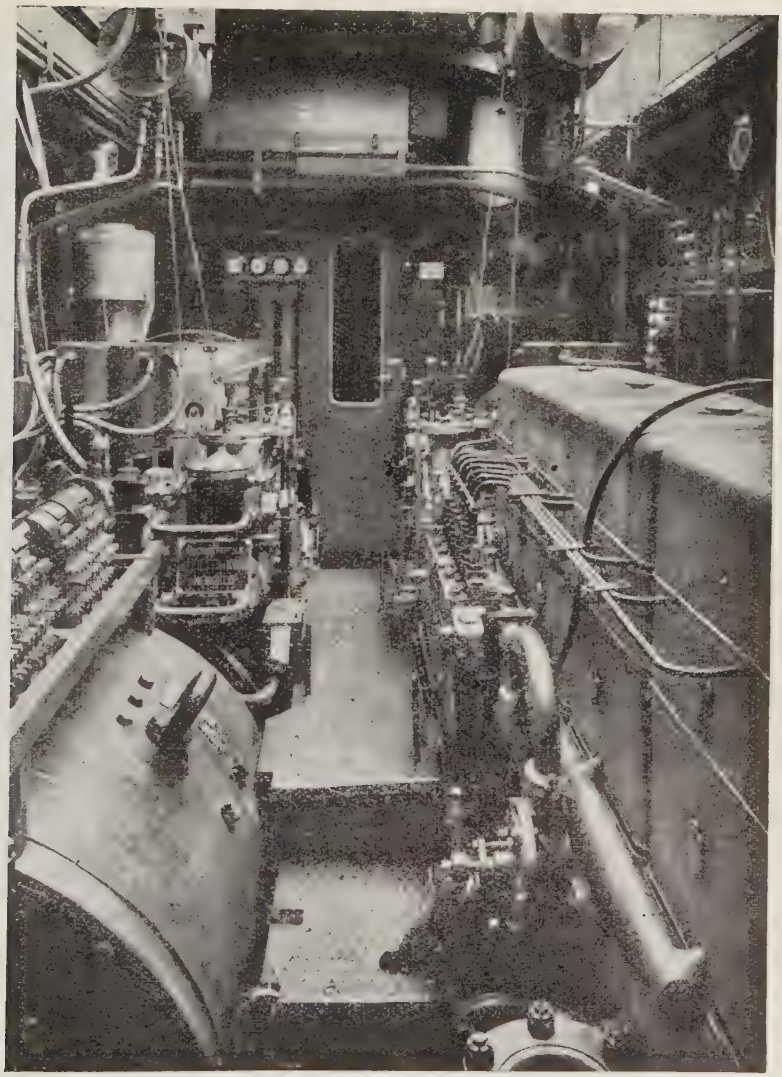


Fig. 19. — View of engine compartment on a Dutch triple railcar equipped with Stork-Ganz 350-h.p. engines.

gines run at about 1 500 r.p.m. and one engine running at 2 100 r.p.m. has appeared (C.L.M., 160 h.p).

For some years the British builders have been using successfully on railcars the A.E.C. (fig. 20) engine (120 h.p., 1 800 r.p.m.) equipping many of the London motor omnibuses, the licence for which in Italy is held by Breda.

This increase in engine speed is resorted to in a moderate way, as if an engine is to be run faster without abnor-

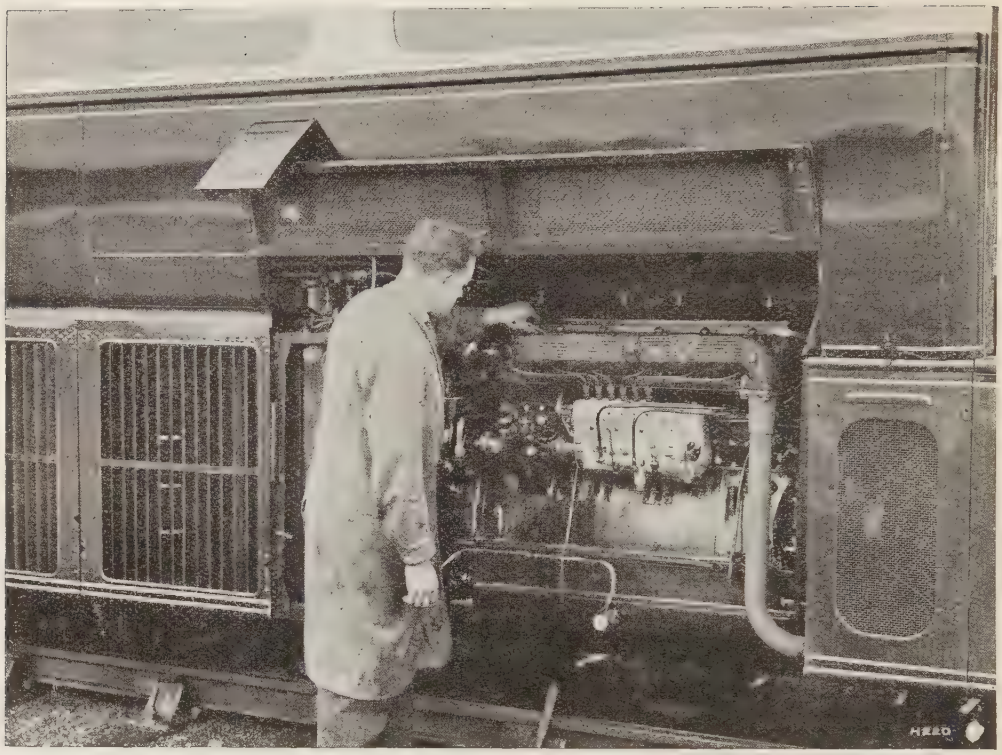


Fig. 20. — Location of the engine on a 260-H.P. A.E.C. railcar *(G.W.R.)*.

mal stresses in the mechanical details or pressures which may upset the oil film, the inertia forces must be reduced.

By diminishing the mass of the moving parts and consequently by dividing the swept volume between a large number of cylinders, advantage may be taken of the experience acquired with small high-speed diesel engines which are already being used on road motor cars ; however the number of cylinders required is too great.

Amongst such engines we would mention the PEUGEOT H. L. 50 which develops 50 H.P. at 3 250 r.p.m. [4 cylinders, 78 × 120 (3 1/16″ × 4 3/4″)—weight 225 kgr. (496 lb.)].

It is to be hoped, however, that metallurgical progress will make it possible to follow recent aircraft practice (use of high-tensile steels and ultra light alloys) and, by building the vehicles very lightly, to facilitate such adaptation.

In the case of the diesel engine, high speeds of rotation involve some injection difficulties : in the pipes from the pumps to the injectors back pressure waves can set up super-pressures and make the injectors work untimely. This difficulty has been overcome by using the injector-pump, which unites the two parts into a single unit, without pipes.

As applied to the C.L.M. 160 H.P. engine, the injector-pump is as easily removed as a sparking plug on a petrol engine.

The two-stroke engine, though on account of its cycle it develops a high power while taking up little space, and

has a low weight per h.p., does not attract further builders though it continues to be made. In France the C.L.M. Works offer a number of two-stroke engines of 160, 200 and 500 h.p., with opposed pistons and two crank shafts connected by gears.

As a matter of information, the ratios of the lengh and width of the 250-h.p. C.L.M. engine similar to those of a 265-h.p. Renault engine are 0.78 and 0.90 respectively, which gives a surface ratio of 0.7 for a power ratio of 0.95.

The respective weights are 5 kgr. (11.0 lb.) per h.p. in the case of the C.L.M. engine, and 7.1 kgr. (15.6 lb.) in the case of the Renault.

In Spain, the Madrid-Saragossa-Alicante Rys. are using the 250 h.p. Burmeister & Wain engine (fig. 21) built in Denmark.

In spite of its relatively low speed (1 250 r.p.m.), this engine, thanks to its 2 stroke cycle, only weighs 6.8 kgr. (15 lb.) per h.p.

II. — Supercharging.

Of the Administrations covered by this report, only the French Railways are using supercharged diesel engines.

We will, however, deal with this subject in some detail, as the first tests have been particularly encouraging and supercharging would appear to meet the requirements of the railcar particulary well.

When supercharging is applied the original engine — save in a few details — can be retained, with its good qualities, and give an increase in power of some 30 %, at the cost of a maximum increase of 300 kgr. (660 lb.) in weight.

Apart from a few supercharged diesels

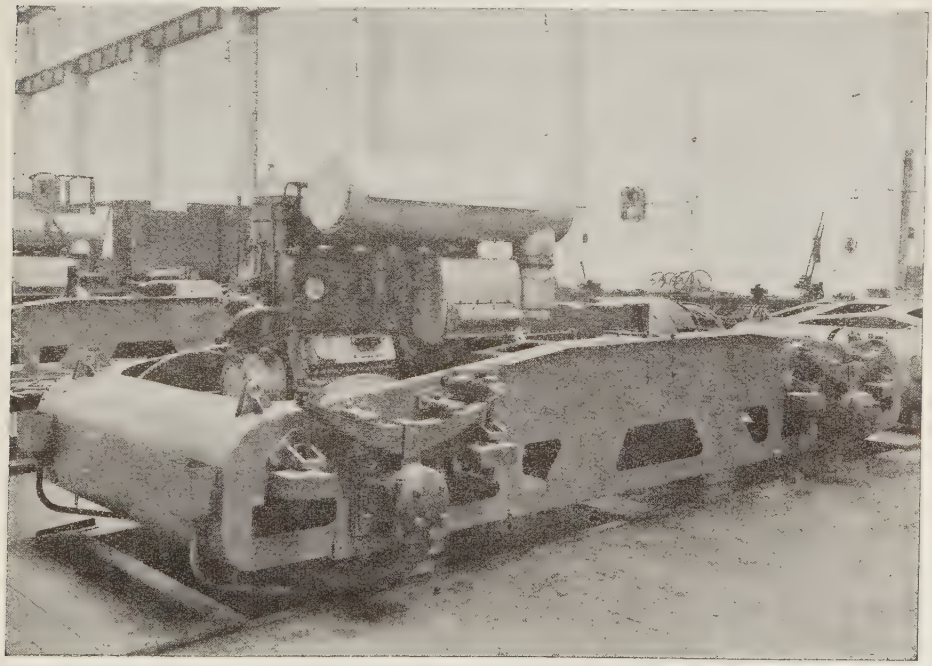


Fig. 21. — Motor bogie carrying the diesel engine and generator, of 250-h.p. Madrid-Saragossa-Alicante Rys. railcars (250-h.p. Burmeister & Wain engine).

on ships, where the question of weight and space are important, it was necessary to wait for the extended use of diesel motors on rail motor cars during the last years to see the technique of supercharging properly developed.

At the present time, though supercharging is used more often on diesel-electric locomotives (1), we may quote amongst the railcars equipped or to be equipped :

11 *S. O. M. U. A.* railcars, and

1 *Franco-Belge* triplet.

Supercharging which consists in feeding the engine with air at a pressure exceeding that of the atmosphere, makes it possible, with a given cylinder volume, to increase the quantity of fuel injected and consequently the maximum pressure, the mean pressure, and the power.

By reducing slightly the compression ratio (from 4 to 5 kgr./cm² = 56 to 71 lb. per sq. in.), the same maximum pressures can be obtained as with a non-supercharged engine, and the parts such as the crank shafts, and big end bearings which have been designed for such pressures, can be retained.

As the compression ratio cannot be diminished below a value giving sufficient pressure to produce the increase in temperature needed to ignite the gas-oil, principally at the moment of starting, when the supercharger is not working, the builders at the present time are limiting the excess pressure of the feed air to 350 gr. (5 lb. per sq. in.).

To obtain the maximum benefit possible from supercharging, the builders have tried to use at the same time this air to scavenge as thoroughly as possible the burnt gases and get a cylinder volume of almost completely fresh air before each stroke.

This result has been obtained by having :

1. simultaneous opening of the exhaust and admission valves during the longest possible time;

2. as high as possible an air compressor pressure, taking into account the limit mentioned above;

3. an exhaust back pressure as low as possible, taking into account the possible use of a turbo-blower.

With this arrangement the fresh air lost during scavenging may be as much as 25 to 30 % of the amount required by the engine; by passing over the pistons, compression chambers and valves, this air brings down their temperature considerably, and reduces the heat stresses proportionally.

The heat it removes, no longer has to be taken up by the cooling water or the oil, and this is shown by the heat balance-sheet below (fig. 22).

This is an important advantage in the case of railcars, as it makes it possible to reduce the radiators, which in themselves and in the water they hold represent a considerable dead weight, and are difficult to install if the power becomes somewhat high and the railcar has to be reversible.

To sum up, supercharging a diesel engine only involves :

1. new adjustment of the valve gear;

2. a reduction in the compression ratio;

3. the fitting of a supercharger.

The builders adapt either compressors driven off the engine (C.L.M. — in this particular case the compressor is used almost solely for scavenging, but the method of fitting would be the same in

(1) 3 *Marine & Homécourt* locomotives for the Congo-Océan Ry. (950 H.P.).

1 *Marine & Homécourt* locomotive for the P.L.M. Rys. (4 200 H.P.).

1 *Fives-Lille* locomotive for the P.L.M. Rys. (4 200 H.P.).

3 *Marine & Homécourt* locomotives for the P.L.M. (600 H.P.).

2 *Marine & Homécourt* locomotives for the Constantine Phosphates Company (600 H.P.).

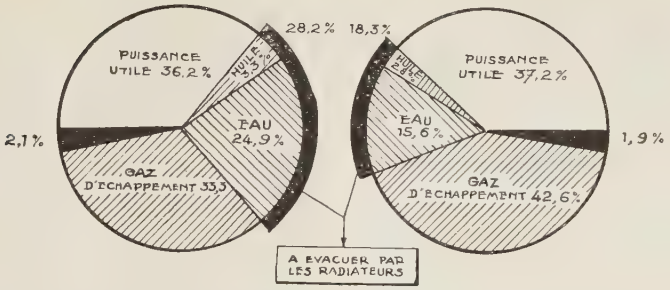


Fig. 22. — Distribution of heat units in a 4-stroke diesel engine : *right*, engine supercharged by means of a turbo-compressor; *left*, non supercharged engine.

Note. — Puissance utile = useful power. — Huile = oil. — Eau = water. — Gaz d'échappement = exhaust gases. — A évacuer par les radiateurs = to be dissipated by coolers.

the case of supercharging), or turbo-compressors working on the exhaust gases.

The mechanical supercharger which is the only one used on flying machines on account of the little room it takes up, consists of a turbine revolving at a very high speed (19 000 r.p.m.) for an engine speed of 1 500 r.p.m.) driven by the engine through suitable gearing.

The coupling between the engine and compressor (fig. 23) includes a centrifugal clutch, which at the same time acts as a torque limiter; it enables the compressor to stand smoothly the engine speed variations.

This type of equipment does not increase the exhaust back pressure, but has to be designed as an integrant part of the engine.

On the other hand, the turbo-blower working on the exhaust gases (Rateau-Buchi) can be fitted on an existing engine, but slightly increases the exhaust back pressure.

The turbo-compressor consists of a single-stage turbine, driven by the high-temperature exhaust gases, which drives a compressor, also single stage.

The compressor wheel is of the radial blade type with a very high peripherical speed.

In view of the progress in metallurgy,

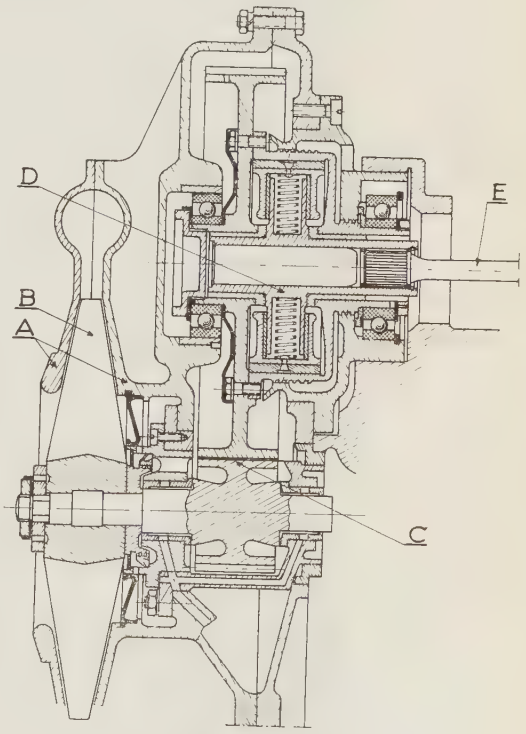


Fig. 23. — Scavenging-air compressor.

A. Stator of compressor.
B. Rotor of compressor.
C. Gears.
D. Torque limiting clutch.
E. Driving shaft.

which has made it possible to build sturdy exhaust-gas turbines, this solution is theoretically the most attractive and the most widely used in practice.

The turbo-blower recovers part of the work lost in the incomplete exhaust, and consequently its low efficiency is of no importance.

As an accessory advantage, it plays the part of a silencer.

Brief description of certain designs.

The S.G.C.M.-M.A.N. 280-H.P. engine (fig. 24), supercharged by a RATEAU turbo-blower, used on the S.O.M.U.A. railcars of the P.L.M. (France), develops 350 H.P., i.e. about a gain of about 25 %. The excess air pressure is about 200 gr. (1.4 lb. per sq. in.).

In February 1937, four railcars of

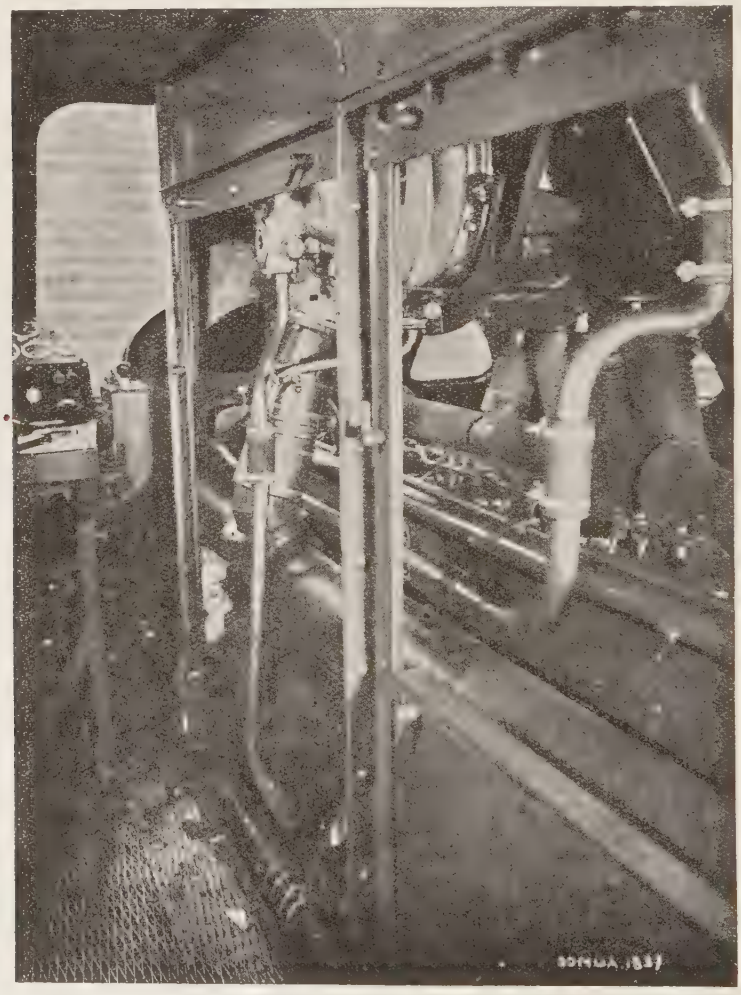


Fig. 24. — M.A.N. 280-H.P. engine supercharged up to 350-H.P., as used on the S.O.M.U.A. railcars of the P.L.M. Rys.

this class were working with supercharged engines, the first having been delivered in October 1936.

The Nord Ry. is at the present time fitting a Rateau turbo-blower on the Maybach 410-h.p. engine of one of the Franco-Belge sets; the horse-power expected is 580, or an increase of 170 h.p., against a weight increase of at most 150 kgr. (330 lb.).

On the diesel-electric locomotive of the Congo-Océan Ry., a 700-h.p. S.G.C.M.-M.A.N. engine (700 r.p.m.), supercharged by a Rateau turbo-blower, develops 850 h.p. continuously and 950 for 6 hours.

Owing to a higher supercharging pressure [350 gr. instead of 300 = 5 lb. per sq. in. instead of 4.25)] and an improved design, the same engine will give 950 h.p. under continuous load and 1 050 h.p. for two hours, in the case of a high-speed diesel locomotive for the P. L. M. (France).

III. — A few constructional details.

With the exception of C.L.M., who have produced a 2-stroke 500-h.p. engine with 8 cylinders in line, and Ganz, who have built a 365-h.p. engine with 8 cylinders in line, all the builders are adopting for their powerful engines the V type cylinder arrangement (450 h.p. Fiat — 265-300-500 Renault — 300 Saurer — 410 Maybach — 400 Frichs — 450 Benz), the U type formerly used by M.A.N. having been completely abandoned.

The V-type engine, with the two banks of cylinders generally at an angle of 60°, presents no manufacturing difficulty other than the driving of the crank shafts by the connecting rods.

In certain engines we find a main rod turning on a crank pin and a small rod attached to the main rod through a pin with needle bearings (Renault engine with short rods), roller bearings (Maybach engine) or brass rings (Renault engine with long rods).

This method, which has otherwise given excellent results, means that the two pistons do not follow the same movement; there is a difference in stroke, and in certain cases abnormal forces acting on the piston surfaces on the main rod side.

On the other hand, forked rods (Saurer 300 h.p. (fig. 25), Benz 450 h.p., Hispano-Suiza 500 h.p. petrol engine) are free from these drawbacks, the two pistons having exactly the same stroke.

In this case the bearing of one rod revolves on the crank shaft and carries

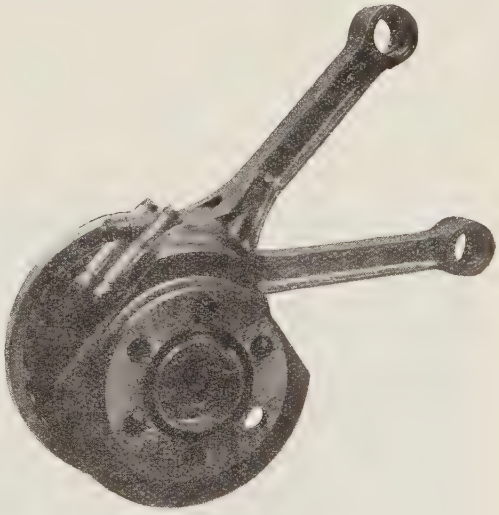


Fig. 25. — Connecting rods and crank shafts of 300-h.p. Saurer engines.

on its outside face the other rod which has only a very small movement relatively to the bearing.

The sides of the rods which rub against one another can be chrome-hardened (Saurer 300 h.p.).

From the metallurgical point of view, the use of special metals has made it possible to increase the strength of certain details (Renault valve — Maybach 410 h.p., gear wheels), but it appears that the most important feature is the almost complete abandonment of white metal

which as a lining would not stand the high pressures and has been replaced by rose metal or lead bronze.

These two alloys are in principle alloys of lead and copper, with the addition of some other metals according to the maker.

Quite special precautions have to be taken in casting these metals so that the alloy remains homogeneous and the lead does not settle on the contact surface.

The rose metal is applied on both parts of the connecting rod end or on the part adjacent to the rod, the other being lined with white metal.

Some builders began by putting the rose metal directly on the connecting rods, but during repairs the operations needed to remove the metal sometimes spoilt the connecting rod.

To prevent this, most of the builders use the rose metal on a detachable bearing, taking care the bearing of the bronze on the connecting rod is as perfect as possible.

As regards the rod ends, one builder (SAURER) uses lead bronze machined in the mass, and pressed on the steel rods, and finally trued up.

The two builders who in 1934-1935 were using roller bearings instead of plain bearings (SAURER for crank shaft bearings — MAYBACH for crank shaft bearings and big ends) remain faithful to this method on their new railcars.

Though SAURER found the results satisfactory, MAYBACH had some difficulties with his 410-H.P. engine at the beginning, owing to the rollers and races of big end bearings breaking down due to the vibration of insufficiently balanced crank shafts.

Thanks to a very complete investigation carried out by the latter builder, both in the German laboratories, and on the railway, (HOLLAND, BELGIUM, FRENCH NORD), the cause of this defect was found and, by fitting the crank shafts with counterweights the defect has been cured.

Their engine has also been made more flexible by asking the railways only to use filtered and decanted fuel oil and by changing the system of injection (central instead of lateral injection — injectors with 4 instead of 5 holes — improvement of the pistons).

There is also a tendency to reduce the calibrating pressure of the injectors (RENAULT from 280 to 200 kgr. = 3 980 to 2 840 lb. per sq. in.) in order to improve the behaviour of the injection pumps. This reduction has been made possible by the progress achieved in the design of injectors which, with these new pressures, give quite as good a pulverisation.

It is curious to note in this connection that the engine with pre-combustion chamber, which can do with a much lower pressure, has not found further adepts, and has even lost ground (SAURER).

The builders have also endeavoured to make the engines cleaner and especially to prevent fuel oil leakage, and projections of oil which are so dangerous from the point of view of fire outbreaks.

For example RENAULT has fitted collectors to recover all oil lost from the injectors and the other inevitable leakages of oil.

SAURER and FIAT cover the moving parts with an oiltight casing collecting the oil vapour produced, by providing a connection between the casing and the admission collector.

Finally, efforts are being made to make certain parts more accessible and easier to repair. The method usually adopted for maintaining the engine (periodical inspections and systematic taking down) calls for such improvements.

* * *

We would not conclude this chapter without reporting the new tendency in the construction of railcar engines (horizontal engines) and without men-

tioning the producer-gas engines put into service by the French State.

The horizontal engine carried under the body saves a good deal of space which can be used for passengers or luggage.

The first horizontal engine was put on the market in France by the Ateliers du Nord de la France et des Mureaux, (D.W.K. licence). This is an 8-cylinder engine developing 165 h.p. at 1 460 r.p.m.

The French Nord has ordered some Peugeot-C.L.M. 250-h.p. horizontal engines for a standard observation railcar.

A Hispano 500-h.p. horizontal petrol engine is also on the market.

There is no particular difficulty in designing an engine of this kind, and the experience with flying machines equipped with star or inverted engines shows that the builders can perfectly well overcome the minor difficulties with regard to lubrication which may arise.

In spite of this, the horizontal engine has not made the same progress in the countries whith which we are dealing as it has in Germany.

Actually, in 1934-1935 the railways had not yet decided to locate the motors under the body, and when the need for powerful engines arose, the majority of the builders preferred to design and build V-type engines, which can be used both in the body and on the bogie, rather than horizontal engines which cannot be easily mounted on bogies (especially 4-stroke engines) owing to the room taken up.

The Panhard-Levassor producer-gas 12-cylinder engine, 210-h.p. at 1 600 r.p.m., is a 400-h.p., 1 800 r.p.m. petrol engine slightly altered by increasing the

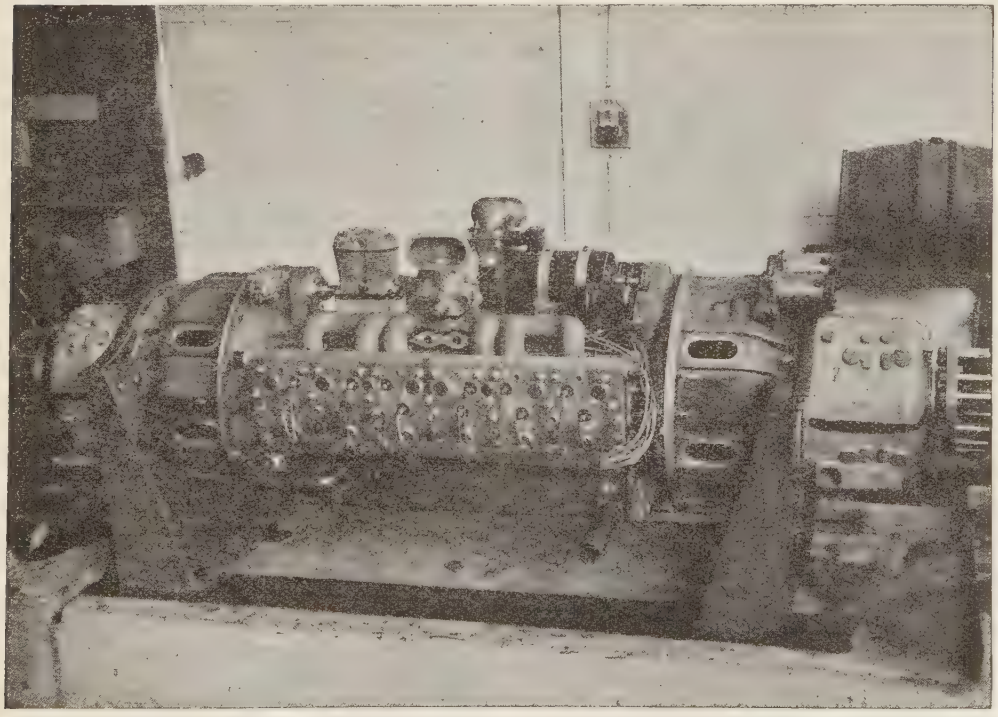


Fig. 26. — 500-h.p. Hispano-Suiza horizontal engine.

compression rate, altering the valve gear, and eliminating the carburrettor.

The producer was also built by PANHARD; it is of the inverted type without pipes, and has refractory lining.

On leaving the producer, the gas passes through a cooler and a filter with cloth strainers.

The fuel used is charcoal, either from old sleepers, or oak or yoke-elm from other sources. In semi-through services, the charcoal consumption in the first case is 80 kgr. per 100 km. (284 lb. per 100 miles), and in the second case 110 kgr. (390 lb. per 100 miles).

This test, carried out to replace imported fuel by a national one, was made on a S.O.M.U.A. railcar (fig. 27), weighing 30 tons empty, driven by a 210-H.P. diesel engine.

There was no difficulty in adapting the engine; the gasometer and particularly the refractory lining presented rather more delicate problems, and at the present time a carborundum lining is being designed.

Fig. 27. — S.O.M.U.A. producer gas railcar of the French State Railways.
Filling charcoal tank.

In spite of these difficulties, the results are most encouraging, and the STATE RYS. have ordered two DE DIETRICH railcars with the same engines, but of slightly higher power (280 instead of 210 H.P.). The EST RY. is equipping, as a trial, with a producer of somewhat different design, a CHARENTAISE railcar, the M.A.N. engine of which has undergone some slight alteration to this end.

* * *

CHAPTER III.

Transmissions.

A steam locomotive can supply its full power to the driving wheels between the speed corresponding to the maximum boiler output down to quite low speeds, without any difficulty. The characteristics of the internal-combustion engine are such that it is impossible for the wheels to be driven directly by the engine, and the function of the transmission is to make it possible for the full power of the engine to be available at the wheels at all speeds, except at very low speeds at which the full power of the motor could not be used as the torque would be excessive.

A well designed transmission must satisfy a number of conditions, the principal of which are the following :

1. The transmission must be adapted to the diesel engine and to the services required;

2. It must be suitable for distant control;

3. The weight and room taken up must be reasonable;

4. The efficiency must be good at all speeds and loads, and the maximum at the most usual speed and load;

5. The first cost and maintenance costs must be reasonable.

1. *Adaptation of the transmission to the diesel engine and the services required.*

The diesel engine having a well-defined maximum torque and only working reliably within well-defined limits of speed, the transmission should allow the engine to work under these ideal conditions, whatever the speed and the load.

The diesel engine moreover cannot exert any torque at low speeds, so that when starting the transmission must be such that the engine revolves at almost normal speed; this condition, easily obtained with electric transmission, is obtained with mechanical transmission by slipping the clutch and with hydraulic transmission by slipping the primary (impeller) relatively to the secondary (runner).

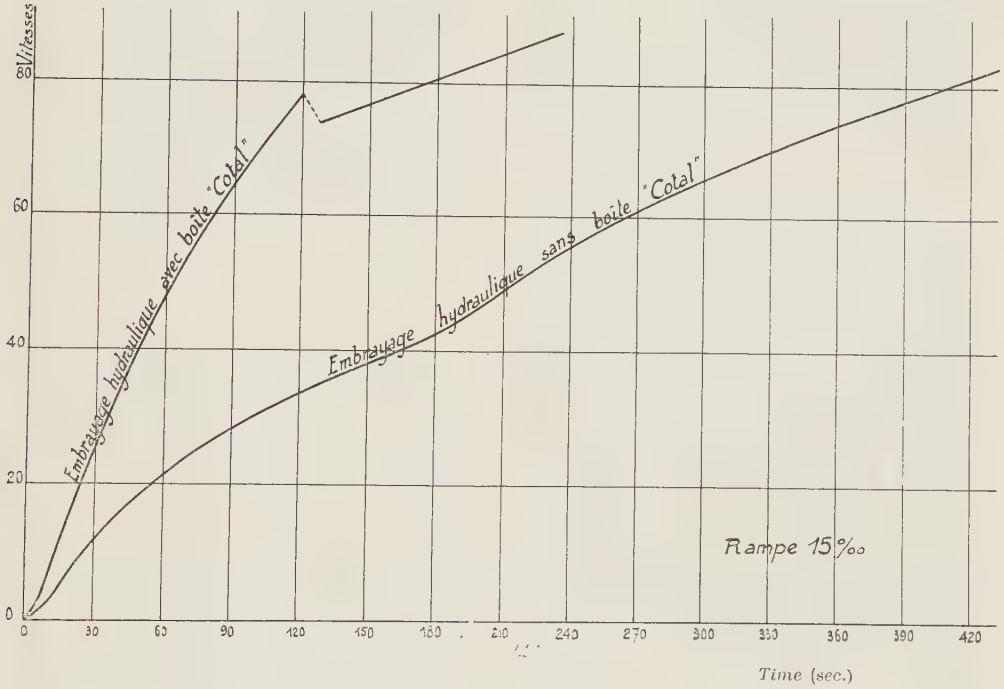


Fig. 28. — Comparative starting curves of two Bugatti railcars, one being equipped with a simple hydraulic clutch (lower curve), and the other having, in addition, a 2-speed Cotal gear box (upper curve).

Note. — Rampe 15 o/oo = 1 in 67 gradient.

The transmission must not only be suitable for the diesel engine, but also for the train service to be operated; for example, the original Bugatti transmission with a hydraulic clutch is capable of giving very good results for a high-speed service with few stops, but it is not suitable for use on a service with frequent stops.

Figure 28 shows the starting curves on a 1 in 67 gradient of two Bugatti railcars, one of which is fitted with a hydraulic clutch, whereas the other has a Cotal two-speed gearbox *in addition.*

These curves show that starting is made much easier when a gearbox is used.

It should be noted that the 96-seater MICHELINES also have a hydraulic clutch with a two-speed COTAL gearbox.

The transmission must also take into account the physical character of the lines over which the car has to work (curves, gradients); the ITALIAN STATE RYS., by suitably proportioning the steps in the mechanical transmission of their railcars have succeeded in operating the cars without difficulty over mountain lines with 1 in 17 gradients.

Therefore, railcars may be introduced with transmissions with different gear ratios, according to the vehicle being worked with or without a trailer.

2. *Suitability for distant control.*

Operating by means of railcars must be very flexible; first of all there must be no question of turning at termini, and it must be possible to increase the capacity of the railcar to meet a rush of passengers, either by adding a trailer or by coupling together two railcars. This raises the distant control problem.

If distant control is easily carried in the case of electric transmissions, it is much more difficult to arrange in the case of hydraulic and mechanical transmissions. Several satisfactory solutions have, however, been retained; we described them in our 1935 report and will deal in this chapter, in a more detailed manner, with their improvements.

3. *Weight and admissible room taken up.*

The transmission must be so designed that the weight is not prohibitive, and secondly it must be easily installed in the vehicle.

The weight of mechanical and hydraulic transmissions and the room they take up increase in direct ratio with the power transmitted, so that the use of a high-speed engine (of low specific weight) makes it possible to have a light transmission taking up little room, hence to obtain a complete power unit of very light weight. In order to reduce still further the weight of the transmission, some builders (S.O.M.U.A., MINERVA, VOITH and MAYBACH, for example) still reduce the torque developed by the engine by additional gearing at the clutch end of the engine.

The use of epicyclic gears reduces the weight of the transmission for high powers; for example, the weight of an ordinary box varies in a 3 to 2 ratio, with the torque transmitted, while the increase in weight of a COTAL box varies almost as the torque transmitted.

Electric, and still more so, hydraulic transmissions generally weigh more than mechanical transmissions; nonetheless in most cases they take up relatively little room, so that the builders have been able to locate them under the floor of the coach.

4. *Acceptable efficiency.*

The efficiency to be considered is chiefly that corresponding to the most usually worked speed; the efficiency at others than this speed, though not of vital importance must, however, be reasonable.

In order to obtain good efficiency at the usual working speeds, some builders start the railcar by means of the transmission they have selected and couple the engine directly to the axles as soon as the vehicle has reached the working speed; thus the LEYLAND railcars of the L.M.S., with hydraulic transmission, have a coupling device for the working speed, and the « Slovak Arrow » type railcars, with electric transmission, also have, for the same purpose, a very ingeniously designed coupling.

Any direct drive mechanism however forms what is tantamount to an interlock between the speed and the engine, and if anything goes wrong with the diesel engine, it is difficult for a driver depend-

ing mainly upon his speed indicator, to appreciate the failure immediately. Certain builders who formerly provided direct drive with the usual working speed, now propose to eliminate the coupler, only retaining the torque converter.

Outside this working speed, the efficiency is of less importance; it should nonetheless be reasonably good.

Voith-Maybach, in their hydraulic transmission for high powers, have been led to change the torque converter as soon as the working conditions differ too much from those giving the maximum efficiency at high speed; three conversion stages are thus provided, and the curves of the hydraulic efficiency under these conditions appear as shown by figure 29.

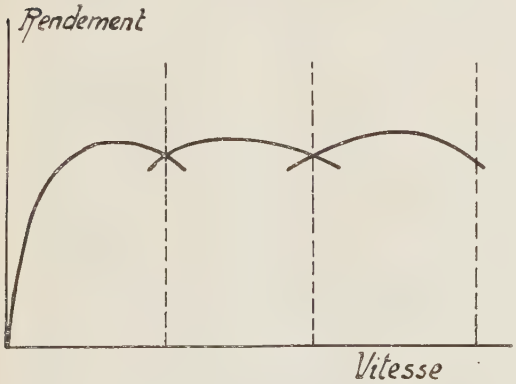


Fig. 29. — Voith-Maybach hydraulic transmission with 3 conversion stages.
Note. — Rendement = efficiency. — Vitesse = Speed.

As regards mechanical transmission, the efficiency can be considered as known before the engine is built; indeed, the efficiency of each gear in the transmission is known, so that the efficiency of the whole is easily calculated. To do this, however, is much more complicated with hydraulic transmission, and still more so with electric transmission.

The efficiencies of the various types of transmission, when well designed, can be more or less the same at the nominal engine power.

The efficiency parameter cannot be used as a basis of comparison of the different systems.

The diagram, figure 30 gives the overall efficiency curves =

$$\frac{\text{effective power at the tread}}{\text{nominal power}}$$

in terms of the speed for a 300-h.p. de Dietrich railcar with mechanical transmission and of a 250-h.p. Bugatti railcar with electric transmission. These curves show quite clearly that up to 90 km. (56 miles) an hour the electric drive is the best on the average. Beyond this speed, however, mechanical transmission is best.

5. *Low cost price and maintenance costs.*

This latter condition can be applied to all the parts of the railcar. As regards the transmission, however, the electric transmission appears to be more costly than the hydraulic, the latter in its turn being more costly than mechanical transmission.

As regards maintenance, we still lack data to make a really reliable comparison between the different types of transmission.

During the last two years, competition between the different types of transmission has continued without it being possible to distinguish any definite trend.

At the time of the enlarged Meeting of the Permanent Commission of the International Railway Congress Association in 1935, the different types of transmission on the railcars of the Railways consulted were as follows :

Mechanical transmission	81 %
Electric transmission	15 %
Hydraulic transmission	2 %
Mechanical transmission with hylic clutch	2 %

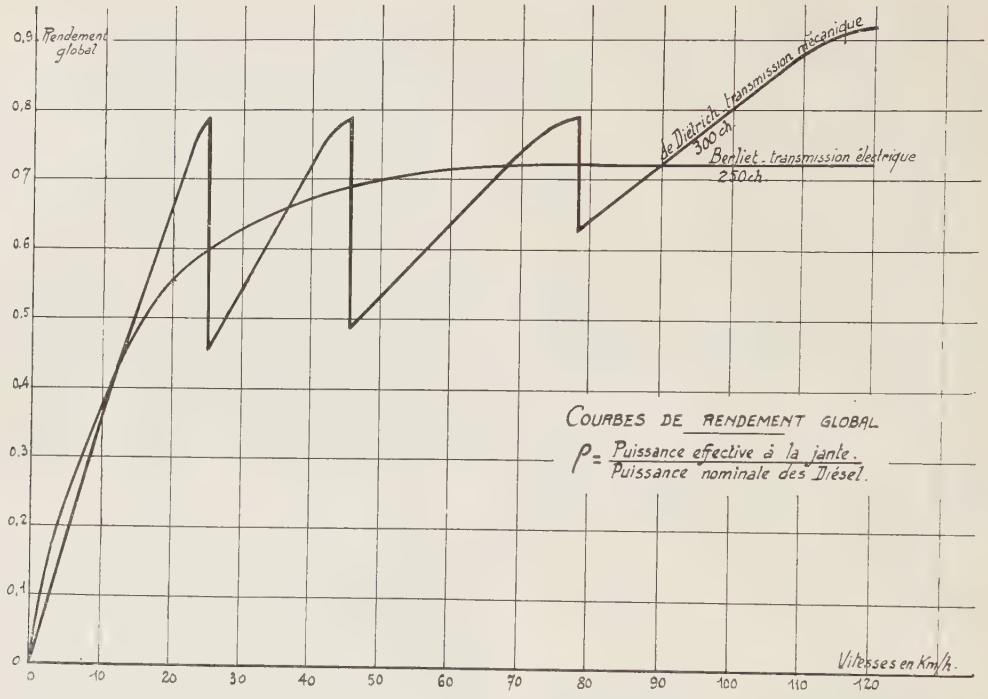


Fig. 30. — Comparative efficiencies of a 300-H.P. DE DIETRICH railcar with mechanical transmission and of a 250-H.P. BERLIET railcar with electrical transmission.

Note. — Courbes de rendement... = total efficiency curves. — ρ = effective power at the tread / nominal power of the diesels. Vitesses... = speeds, km./h.

On the 1st October 1936 the distribution was as follows :

Mechanical transmission	83 %
Electric transmission	10 %
Hydraulic transmission	2 %
Mechanical transmission with hydraulic clutch	5 %

The railcars ordered or under construction at the same date were divided up as follows :

Mechanical transmission	85 %
Electric transmission	9 %
Hydraulic transmission	2 %
Mechanical transmission with hydraulic clutch	4 %

Mechanical transmissions.

The original principle of the mechanical transmissions has been retained and their component parts are still the same. For some years it has been realised that there were increased possibilities in mechanical transmissions, and to-day gearboxes up to 500 H.P. are on the market.

The experience of recent years shows that for the mechanical transmission to work properly, and therefore with the lowest maintenance cost, the different parts must be of ample dimensions. Some Railways have had trouble through having used too small gear boxes to save first costs.

The results obtained are satisfactory and the mechanical gearboxes wear very well; the roller bearings of the shafts are more delicate than the gears. As a rule synchronisation devices, when used, are still the weak point of the boxes.

As we have already seen, in this kind of transmission the force is transmitted to the wheels through several stages of gearing. When the starting curve of a railcar with mechanical transmission is examined, it will be seen that the speed curve does not increase constantly but slightly decreases at the moment the gear is changed; this is due to the power of the engine not being transmitted while de-clutching to change gear. Some builders have endeavoured to reduce to the strictly necessary minimum the time required to change speed and then to get a continuously rising curve by means of ingenious devices, the value of which has not yet been proved by experience (Minerva, Ardelt, Hobbs).

The choice of the gear range is of great importance, and some railways have had difficulty in service because one stage of the gear box was badly designed, and the speed of the engine dropped too much at the moment of changing gears. It appears that the working speed of the engine should not fall below two thirds of its nominal speed, when changing gears.

Moreover some builders have reduced the variations in the speed of the diesel engine by increasing the number of stages in the gear box. At the present time gear boxes with 6, 7 and 8 speeds are on the market (Minerva, Fiat, Maybach).

Some builders have provided, for starting, an intermediate position between neutral and the first speed (Winterthur); others have fitted the servomotor in such a way that the time taken to clutch in is longer between neutral and the first speed than between the other speeds (Renault, A.B.J.).

To reduce the noise of the gears,

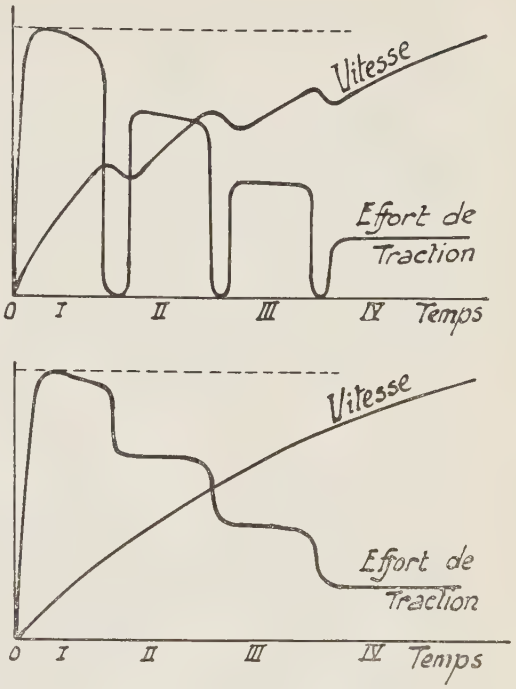


Fig. 31. — *Top* : curves relating to an ordinary gearbox;
Bottom : curves corresponding to an ideal gearbox, without interruption of drive (dead time) when changing speeds.

Note. — Temps = time.

some builders have given up straight gears in favour of the helical (300-h.p. Renault) or oblique wheels (300-h.p. Winterthur).

We think a brief description of the following recent transmissions will be found interesting :

Renault, 500 h.p.
Minerva, 270 h.p.
Cotal, 450 h.p.
Winterthur, 320 h.p.

Renault 500-h.p. gear box.

The 500-h.p. Renault gear box is of the constant mesh type.

The dogs are on the secondary shaft

on which the 1st, 2nd, and 3rd speed gears are carried loose on conical roller bearings.

The speeds are changed by double clutching, the driver having before him a speedometer which enables him to change speed when the engine is revolving at the speed corresponding to this new speed. The change is made more certain by means of the synchronising cones on the dogs.

This gear box is controlled by compressed air in conjunction with electro-valves. Mechanical and electrical safety devices are provided to prevent simultaneous movement of two dogs and also to prevent the clutch being let in before the new speed is engaged.

When several railcars are coupled together, the arrangement is such that it is impossible to engage different speeds.

270-H.P. Minerva gear box (fig. 32).

Messrs. Billard are now using the MINERVA system pre-synchronised gearbox

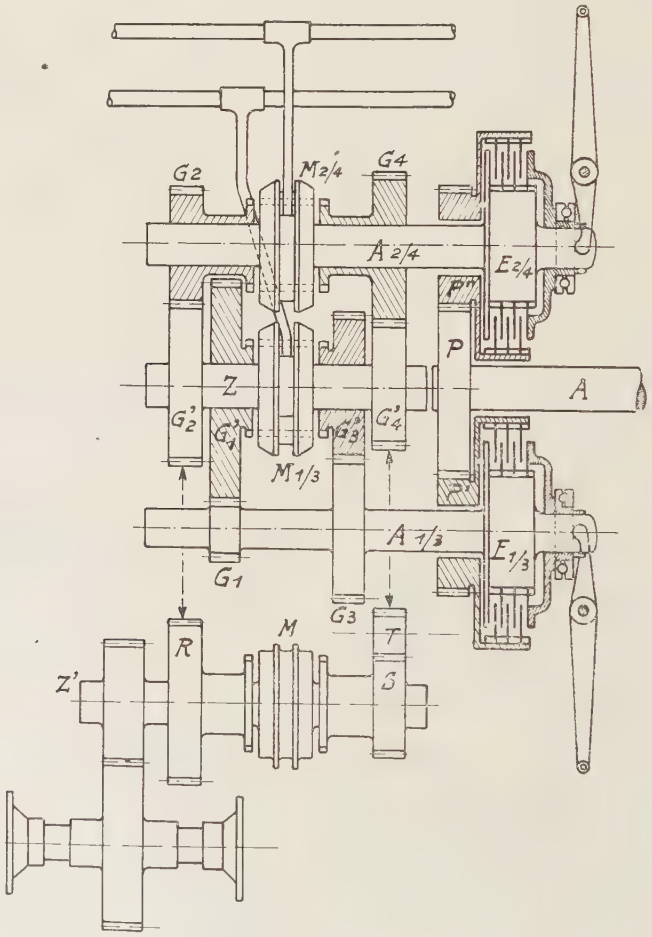


Fig. 32. — MINERVA gearbox for 270-H.P., 1 500-r.p.m. engine (Railcars for Corsica).

in a number of railcars for Corsica, with engines developing 270 h.p. at 1 500 r.p.m. This box has 4 speeds, each of the 4 speeds being obtained by engaging the dogs of the corresponding pinion. The essential advantage of the box is that the change is prepared by pre-synchronisation, thanks to which changing from one speed to another can be done practically without any power interruption.

The controls are arranged in such a way that the selection of a new speed first of all involves, with pre-synchronisation, the dogging together of the gears corresponding to this new speed, the clutch controlling it having been previously disengaged. During this time the vehicle continues to be driven through the gear to be abandoned. When the new speed has been synchronised and the dog behind its clutch disengaged, automatically and almost simultaneously the gears are changed, the drive ceases to be obtained by the speed until then in action, to be taken up by the new one selected. Naturally the disengaged dog returns to neutral. Consequently the drive is not interrupted and the acceleration of the vehicle is not reduced.

450-h.p. Cotal gear box (fig. 33).

Messrs. Cotal have just built 2 boxes for the Italian State's triplets; these gearboxes, designed to transmit 450 h.p. at 1 500 r.p.m. have 8 speeds. They weigh 740 kgr. (1 630 lb.) with bronze casing [they would only weigh 630 kgr. (1 410 lb.) if they were fitted with an ordinary casing]. They take up much less room than the boxes of another design used on similar railcars (length about half).

The principle of this box is the same as that of the smaller-capacity gearboxes built by the same firm; it is characterised by using hypocycloidal trains of wheels, with good efficiency and high transmission capacity in a small volume.

Like the gearboxes mentioned above, no two speeds can be engaged simultaneously; the consumption of current is 200 watts at the normal voltage.

The electro-magnets in action are

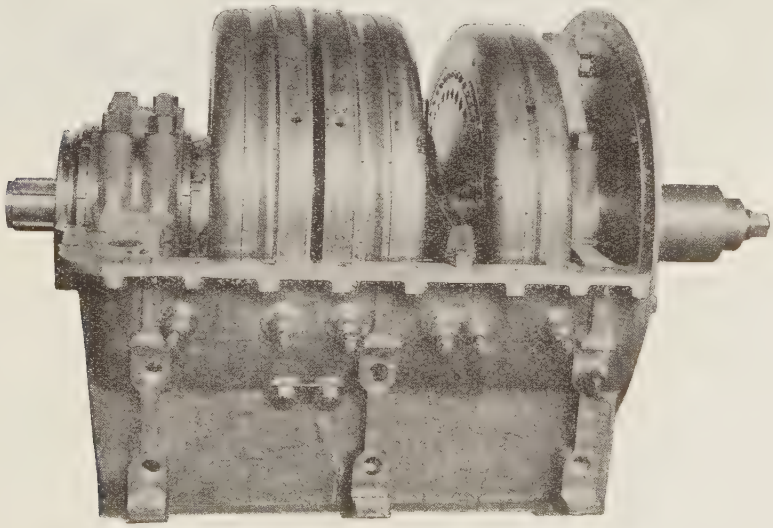


Fig. 33. — Cotal gearbox for 450-h.p., 1 500-r.p.m. engines (Triplet railcars of the Italian State Rys.).

veritable torque limiters which prevent any part of the box being overloaded.

320-H.P. **Winterthur gear box** (fig. 34).

The SWISS LOCOMOTIVE and MACHINE WORKS, WINTERTHUR supplied the Belgian National Railway Company with a gearbox to transmit 320 H.P. developed at 1 500 r.p.m. This box has been in continuous use for a year.

Like the other boxes of the same builder, it has the following features :

toothed wheels always in mesh;

clutches inside the secondary wheels;

clutches engaged and disengaged by oil under pressure.

The power of the engines is transmitted through a flexible torsion coupling and a connecting shaft to the primary shaft of the gear box. The connecting shaft is fitted with a flexible joint. The primary shaft of the gear box carries the pinions of the 4 speeds whilst the secondary shaft carries the 4 corresponding large wheels in which are fitted the oil-operated clutches. On the secondary shaft are also keyed through a free wheel, the two gears driving the reverse gear.

The gear ratios are :

1 : 4.6, 1 : 2.86, 1 : 1.85, 1 : 1.29;

the teeth of the first and second speed

Fig. 34. — WINTERTHUR gearbox for 320-H.P., 1 225-r.p.m. engines. (Belgian National Rys. Co.).

gears are straight, and those of the 3rd and 4th, skew.

The control valve is arranged for 6 positions :

0, neutral,

D, starting,

I to IV, the four speeds.

Gear boxes designed to transmit 290 H.P. at 1 200 r.p.m. have been fitted on two high-speed railcars belonging to the SWISS FEDERAL RYS. (average distance run per railcar 110 000 km. = 68 350 miles), and 75 boxes transmitting 300 H.P. at 1 500 r.p.m. are now being supplied for the standard rail motor cars of the FRENCH MAIN-LINE RAILWAYS.

This maker's latest gear boxes transmit 500 H.P. at 1 500 r.p.m., the principle remaining unchanged; provision is made for carrying the whole transmission on the bogie.

* * *

Hydraulic transmissions.

Hydraulic transmission is used to a limited extent only on the Railways replying to the questionnaire.

The L.M.S. have three small 130-h.p. Leyland railcars with Lysholm-Smith drive. With this gear the cars can make a fast start without shock, without the driver having to have any special manual dexterity. The change to direct drive and inversely cannot be felt by the passengers and does not put any sudden load on the engine; the pick-up is never harsh.

The Bugatti and Michelin railcars are equipped with a hydraulic clutch. Tests show that this clutch reduces the overall efficiency of the transmission by 3 to 5 % according to the speed and load.

One of the de Dietrich railcars has had its gear box and clutch replaced by a Voith system two-stage turbo-converter (coupler and converter).

On railcars fitted with several engines and, therefore, several hydraulic clutches, excessive heating of these clutches has been experienced; this heating occurred when, through the failure of one engine the whole load was distributed over the remaining hydraulic clutches.

* * *

Electric transmissions.

We will not come back to the descriptions of the principal electric transmissions given in our 1935 report as such transmissions have remained much the same.

Electric transmissions are generally used on high-power railcars. This drive has been tried, however, on smaller vehicles as well.

The electric transmission has been criticised for its lack of simplicity. It must be admitted, in favour of the builders of this type of transmission, that the requirements of the diesel engine builder are greater, as a rule, when he knows his engine will be coupled to an electric transmission. If no more were required from an electrical transmission than from a mechanical one, it might perhaps be possible to simplify the former.

Experience shows that the electric equipment must be designed so as to be very little affected by temperature changes and the Railways now attach considerable importance to this feature.

In addition, if the diesel engine fails (as for example through the injection nozzle of one or several cylinders becoming choked) the power taken by the transmission must drop quickly without the speed varying very much, so as to avoid the motor having to operate within unfavourable speed ranges.

Some builders are considering for future designs the use of fully suspended traction motors driving the axles through cardan shafts and bevel gears, with a view to protecting the transmission between the electric motors and the wheels in the event of skidding, have introduced a friction clutch (torque limiter) so as to limit the load transmitted. This arrangement has the further advantage that the traction motor can be cut out if it should fail in service; the isolation of the motor will then prevent the damage being aggravated.

Distant control.

Distant control under present conditions is a very difficult problem, as identical vehicles now require to be worked as twin-units or to be coupled together.

At the present time the distant-control systems are operated by compressed air, electro valves, or purely electrically.

Compressed air is always used in continuous control gear such as the control of the injection (Renault, Standard, etc.) and that of the beginning of the clutch engagement (de Dietrich, Sau-

RER). A compressed-air flexible pipe and coupling have to be fitted, for each distant-controlled device, when railcars are working coupled together. Control by electro-valves is being used much more extensively. Good results are obtained if the electro-valves are well made. They are used whenever the part controlled is designed to take one of two positions only.

Direct electric control is used with some mechanical transmissions (DE DIETRICH, SAURER), and especially in connection with the COTAL gearbox.

Distant-control is very complicated owing to the control transmission gear to be provided. In order to avoid this necessity, it is often admitted that, when several railcars have to be coupled together and worked as a multiple-unit, each railcar retains its own driver who then has to operate the various control devices himself.

Axle drives.

The axles are driven through bevel or worm gear.

The MICHELINES are chain-driven, with good results. Some Railways have tried chains on heavy railcars, but this practice has not become general.

Worm drive seems to be going out. Some Railways have had trouble with railcars having two driven axles and attributed it to the driving worm gear. The trouble ceased, however, when the drive to one of the axles was cut out and the whole power transmitted through one worm gear.

The axle driving gear should be so designed that it can be taken down without removing the wheels.

Reverse gear.

Reverse gears with straight or bevel gear wheels are entirely satisfactory.

Universal and flexible joints.

Experience shows that these joints must be made amply large enough if they are to give good service.

Conclusions.

Under present conditions it may be said that well designed mechanical transmissions have been completely satisfactory up to 300 H.P. on all Railways; 500 H.P. transmissions (RENAULT) were put into service at the beginning of 1936. On long runs they have been satisfactory; as regards stopping services there is still too little information to come to any conclusions.

450-H.P. FIAT and COTAL mechanical transmissions are being tried in Italy. Well designed and carefully manufactured mechanical transmissions are more efficient than any other transmission of similar power.

Electric transmissions have given excellent results on high-power railcars with engines of 400 H.P. and over. They are very heavy, complicated and more costly than mechanical transmissions, but have the great advantage of reliability when working in multiple-units.

Hydraulic transmission is making progress and now seems to be favoured for all powers. If however the efficiency of such turbo-gear is to be kept at a suitable figure, it must consist of a series of hydraulic converters completed by gears. The transmission then becomes a mechanical gearbox protected at each end by fluid clutches.

* * *

CHAPTER IV.

Brakes and running gear.

Brakes.

The classification of brakes into three classes, service, emergency, and stand by, as proposed in the 1935 report, must be extended by including a fourth class, the slowing-down brakes.

The theoretical principles of braking,

previously gone into, have been applied in practice very extensively during the last two years. The result has been the introduction of various devices known as self-regulators, anti-skid gear, etc., which have improved considerably the braking of railcars with steel tyres, which have low adhesion on greasy rails. The still favourable position of the Michelines as compared with metal-tyred railcars must be mentioned; the adhesion of their pneumatic tyres is much better on both dry and wet rails. These vehicles, the loads and speeds of which have been increased, have also benefited from the considerable improvement of the drum brakes.

I. — Service brakes.

Before considering the new devices intended to reduce the margin between the theoretical and practical maximum braking distances required for safety, when arriving at the safety factor to be allowed in the brake constant to avoid any likelihood of the wheels being dangerously skidded, it is useful to state the position as regards the latest knowledge available on the friction elements themselves or on the parts transmitting the brake power developed by the service brakes used on railcars.

A. — *Brake blocks.*

The brake blocks usually fitted on the railcars are those used on the other rolling stock, i.e. cast steel backs carrying detachable cast iron blocks. Many railcars have only one block per wheel. This results in extremely simple brake gear and is of value in the case of railcars with relatively low axle loads.

In the case of heavy vehicles, requiring heavy braking, the classic design of two blocks per wheel must necessarily be used.

Some Railways, for example the French Est and State Railways, since 1936, have been carrying out trials with special asbestos composition blocks, an interesting feature of which is that they have a constant coefficient of friction at varying speeds, like the asbestos cheeks used on drum brakes. A brake of this kind is quite different from a drum brake, as regards the principle on which its design is based, as it is from the N. R. brake with double cast iron and asbestos blocks described later on, if we consider it in relation to the adhesion of the vehicle which varies with the condition of the rail. Indeed, whereas in the case of the drum brake the friction members are protected from the weather and the retardation is the same, whether the rail be dry or wet, the friction of asbestos brake blocks on the tyres can vary considerably when the state of the tyre surface changes with the surface of the rails. Experience has shown that the extent of these changes depends essentially upon the composition of the lining used; the object of the tests in hand is to evolve a composition of the friction material such that the coefficient of friction on a dry tyre or a wet tyre follows a law of decrease parallel to that of the adhesion under the same rail conditions. These tests are well in hand.

Following up another idea, several Railways are carrying out tests with a view to reducing the unit surface pressure of the brake blocks on the tyres; this problem has arisen since the first applications of brakes with self-varying air pressure described later on and which, as they bring into play on each wheel, at least at high speeds, much greater efforts than those customary with ordinary brake blocks, heat the blocks too much and shorten their lives, as well as spoiling the braking effect by reducing the coefficient of friction. Two solutions have been tried to increase the bearing surface of the shoes and in this way reduce the pressure per surface unit :

— brake block gripping the flange;

— the brake block in two articulated sections.

The first type, after encouraging results from the braking point of view when the blocks were well worn in, had to be given up because they caused disquieting cracks in the flanges.

The two-part articulated brake block has been fitted upon the motor bogies of the triple Renault railcar of the FRENCH STATE RYS., the ordinary cast iron block, even when two blocks per wheel were used, being insufficient to apply adequate effort to brake this vehicle satisfactorily, the axles of the centre bogie of which carry nearly 20 tons.

Contrary to what was thought at first, the efficiency of these blocks is little better for a rise in temperature comparable with that of the ordinary brake blocks on the other railcars, in spite of their larger surface.

Interesting tests of two-section shoes have also been carried out in France on the passenger carriages of the FRENCH STATE and P.L.M. Railways.

These tests have shown the necessity for increasing the friction surfaces and for reducing the pressures with which the brake blocks are applied on all heavily loaded axles when these are to be braked to the maximum, particularly in conjunction with the use of self-varying brakes.

The adjustment of the brake gear and any brake block play on railcars is usually done by hand. Some railcars are fitting automatic slack adjusters for trial, but this equipment is frequently less attractive on rail motor cars than on ordinary stock. Then too, the brake gear is usually simpler, with less parts liable to play, each bogie in most cases being equipped with its own brake gear; on the other hand the rail motor cars running as separate vehicles or in rakes of 2 or 3 vehicles with slight differences or delays in the braking of one bogie relatively to another or of one section to another has not got the same drawbacks as in the case of long trains.

Automatic brake rigging adjusters are nonetheless indispensable in certain cases : for example, on railcars with hydraulic brakes, when the capacity of the pumps is insufficient to completely fill the brake cylinders, when a number of the brake blocks are nearly worn to the limit, or on railcars fitted with diaphragms instead of brake cylinders, which on this account only allow slight movements of the shoes. Certain brake systems such as the PIEPER oleo-pneumatic brake, which by design, has in the case considered, a fixed point at the end of an oil piston, automatically regulates the play of the brake blocks.

The speed of application of the brake blocks is always an important matter. On the high-speed railcars, in particular, it is very important that a *quick* braking action should be obtained; at 140 km. (87 miles) an hour, each second lost in transmitting the brake pressure to the brake blocks represents an increase of 40 m. (131 feet) in the stopping distance. To increase the rapidity of action of the brake between the moment the driver operates his valve and that when the brake action commences to be felt, endeavours have been made :

1. to suppress time lag in the rigging;

2. to increase the rapidity of the braking action itself.

In order to obtain quick response when applying the brake shoes, a number of builders have adopted hydraulic brakes, but usually this arrangement is only used in conjunction with drum brakes.

The usual method is to simplify the rigging by bringing the cylinders nearer to the wheels. In most cases there is a separate rigging on each bogie, and two cylinders are provided per bogie, thereby avoiding the use of horizontal compensating levers; sometimes the rigging is reduced to its simplest form by using a brake cylinder per wheel,

or even per block. The use of independent cylinders on the bogie, in addition to the advantages mentioned, also is a more reliable method in the case of vehicles running as single units than the classic method with a single cylinder under the carriage frame. In the case of the rigging getting out of order, loss of a pin for example, there is always at least one bogie braked out of the two.

On many railcars fitted with the direct-action brake, the air from the main reservoir, in order to pass to the brake cylinders, has to go through the driver's valve; this method was adopted at the beginning by many builders on account of its extreme simplicity. It also gives a sufficiently rapid braking action, the pipes not being long enough on a single vehicle to cause any serious charge losses, and excessive delays in filling the cylinders; however, with the increase in speed of fast multiple-unit railcars, and on the other hand the practice of coupling single railcars together, an attempt has been made in the last two years to speed up the action of the direct brake. For this purpose, brake builders have prepared accelerating relays of various types, operated by the driver's valve which puts the brake cylinders into direct communication with the auxiliary reservoirs by short pipes capable of a large delivery. Only a small volume of air passes through the driver's valve, and the charge losses are a minimum, so that relay control is very quick. (Jourdain-Monneret direct brake.)

Finally, always with the object of speeding up the brake application, some railways are testing railcars equipped with electrically-controlled brakes.

B. *Drum brakes.*

Drum brakes with lined cheeks, although they allow of greater deceleration than brakes with ordinary brake blocks, have not been developed during the last two years like the latter. Indeed they very soon come up against serious difficulties which as a rule limit their use to railcars with lightly loaded wheels. These difficulties principally concern :

— dissipation, in the form of heat, of momentum absorbed ;

— wear and renewal of the linings or drums.

From the beginning it was felt that if the drums were not given ample dimensions in view of the momentum to be absorbed, the pressure of application of the linings per surface unit led to overheating, which damaged the interior faces of the drums and consequently caused very rapid wear of the linings. The increase in the size of the drums was admittedly necessary, but progress in this direction was frequently limited by the constructional gauge when the drum was outside the wheel at the end of an axle, or by the lack of space between the wheels and the springs in the opposite case. The brake manufacturers then endeavoured to perfect the friction surfaces themselves : the drums and linings.

As regards drum design interesting progress was made by using centrifugal cast iron instead of steel; thus, thanks to the improved homogeneity of the material as regards friction, local overheating and the consequent deformation of the drums, so harmful as regards the behaviour of the linings, could be prevented. The lining material was made the subject of many investigations, which, if they were to achieve the end in view, had to be carried out in conjunction with research on the quality of the drum material. The life of these linings, moreover, varies according to the use made of them and consequently depends on the speed and nature of the services worked.

Since the first designs appeared — and they were often disappointing — considerable progress has been made by applying the principles given above.

For instance, on the NORD RY. (DECAUVILLE railcar) and the P.L.M. (SOMUA railcar) linings on railcars working local services with very frequent stops currently cover 30 000 km. (18 600 miles).

The ITALIAN STATE RYS. almost exclusively use drum brakes on their railcars, the pattern used having moulded linings giving very satisfactory results, as they last 60 000 to 100 000 km. (37 300 to 62 000 miles).

This type of brake is also used on various railcars by the BELGIAN and DUTCH Railways. The latter are desiging a new adaptation in the form of asbestos-faced disks fixed on the wheel centres under their triplets.

In ENGLAND, the GREAT WESTERN RY. is using successfully drum brakes on its light LEYLAND bogie railcars.

The conclusion can be drawn therefrom that the drum brake proves interesting when used on very light rolling stock with which no big retardation effort is required, and on which a great braking efficiency, together with an appreciable weight saving, can be obtained. It is recommendable to locate it outside the wheels, in order to reduce the expenditure on lining renewals and drum repairs.

C. — *Improvements made in the service brakes to make a better use of the adhesion.*

Besides the progress made in the design of the friction elements and the parts used to apply them, the brake makers or the Railways themselves have for the last two years endeavoured to devise means for going closely into the theoretical problem of maximum braking with existing or new brake designs. The ideal would be that, for each pair of wheels, the curve at the different speeds of the retarding effect at the tread, and the curve of the adhesion for the same pair of wheels at the same moment should coincide, without the wheels picking up. Picking up occurs as soon as the curves intersect.

In order to get nearer to this theoretical result, several methods have been applied with compressed-air brakes.

1. — *Self-regulating devices.*

The pressure at which the brake is applied and the retarding force being proportional to the air pressure in the brake cylinders, an endeavour has been made to vary this pressure in terms of the speed of the vehicle by axle-driven fittings known as self-regulators. In the case of block brakes, the air pressure has to be reduced as the speed diminishes, so that the slope of the curve of the retarding force, which at constant pressure is greater than that of the adhesion curves corresponding to various conditions of the rail (fig. 35).

Contrariwise, in the case of drum brakes, the retarding force curve which is practically constant, without any slope, the opposite has to be done. (Self-regulators, moreover, have not yet been applied to drum brakes, but are being considered in connection with the DECAUVILLE railcars under construction).

The curve of the retarding forces and the adhesion curve can only be made to coincide by simultaneously adjusting the self-regulator on the one hand and the initial air brake pressure on the other. The initial pressure should be set at a fairly low figure, to prevent the wheels picking up on greasy rails, i.e. this pressure should be based on a curve of poor adhesion. The diagrams, figures 36 and 37, show the principles of the JOURDAIN-MONNERET and WESTINGHOUSE self-regulating systems, the first regulating the pressure in the brake cylinder by controlling its exhaust by means of a centrifugal regulator, whilst the second regulates the pressure at which air is admitted into the brake cylinders, by adding at a certain constant air pressure which would not skid the wheels, other

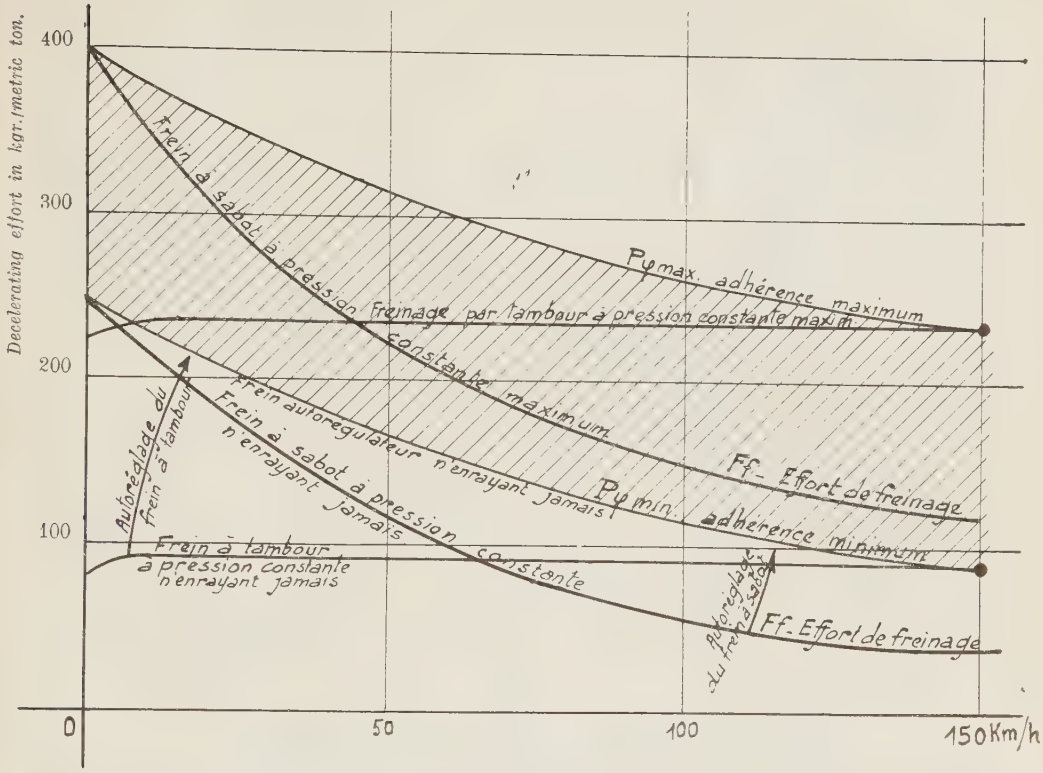


Fig. 35. — Braking curves relating to the ordinary block brake and to the drum brake.

Explanation of French terms:

P φ max. adhérence maximum = maximum adhesion. — Frein à sabot à pression constante maximum = block brake, at constant maximum pressure. — Freinage par tambour à pression constante max. = drum brake, at constant maximum pressure. — Effort de freinage = braking effort. — Frein autorégulateur n'enrayant jamais = self-regulating brake with which wheels never pick up. — Autoréglage du frein à tambour = self regulation of drum brake. — Frein à sabot (à tambour) à pression constante n'enrayant jamais = block (drum) brake at constant pressure, with which wheels never pick up.

air at a pressure proportional to the square of the speed of the vehicle.

The drawback of these systems is that when the initial pressure is set, as it must be low enough to prevent skidding when the adhesion is poor, a large possible braking power — between the retardation curve and the adhesion curve — is not made use of when the adhesion is good (hatched area of fig. 35).

Among the self-regulating systems, we wish to mention also the Piganeau brake, which has been applied to standard railway rolling stock and is to be tried shortly on railcars. This brake makes use of the centrifugal force of a revolving mass, which is made to rotate at high speed at the braking moment, by means of a roller keyed on an axle. The force exerted by this servo-brake is consequently the greater the higher the vehicle speed. It is combined with a standard constant air pressure brake, the action of which is moreover used to apply the roller on its flywheel at the beginning of the brake application.

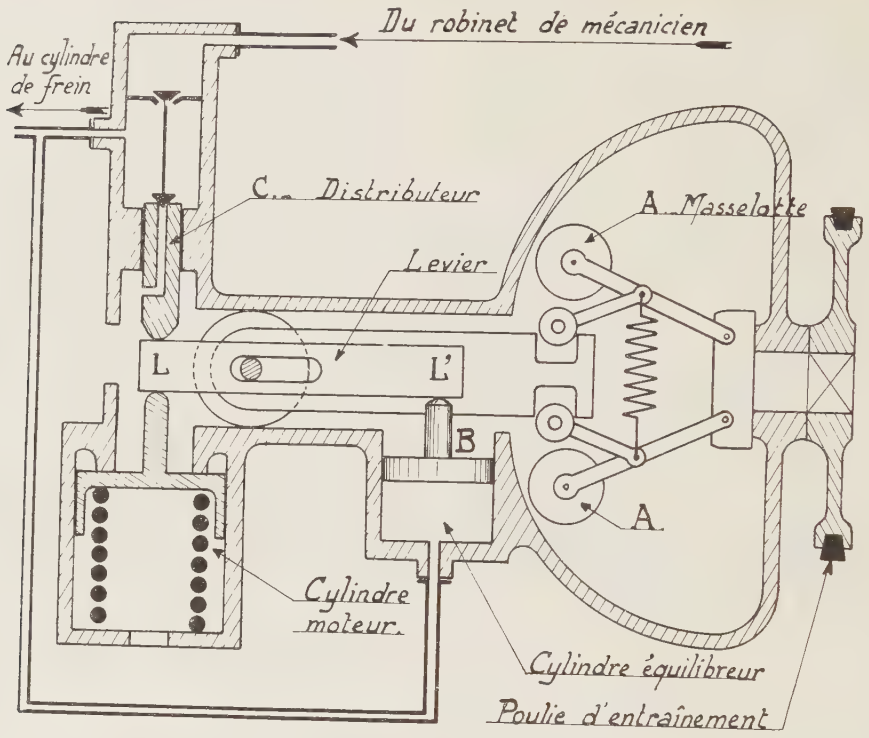


Fig. 36. — J.M. triple valve for braking proportionally to the speed (straight action brake). When the speed drops the weights A close in, the bearing point of lever LL' moves to the left and the action of piston B on the lever forces the valve down, thus allowing a quantity of air from the brake cylinder to be exhausted to atmosphere.

Note. — Au cylindre de frein = to brake cylinder. — Du robinet du mécanicien = from driver's valve. — C. Distributeur = triple valve. — Levier = lever. — Masselotte = weight. — Cylindre moteur = driving cylinder. — Cylindre équilibreur = equalizing cylinder. — Poulie d'entraînement = driving roller.

2. *Equipment designed to release skidded wheels and equipment intended to prevent the wheels from picking up.*

Attempts have been made to stop skidding once it has begun, by means of a special device for regulating the initial air pressure at a higher value than that fixed by the strict non-skidding condition. Devices known as «désenrayeurs» (skid correctors) reduce the brake cylinder pressure to zero as soon as the wheels pick up. The original air pressure can then be regulated so as to obtain a brake power of 140 to 150 % at high speeds. The stopping distances in most cases are then definitely shortened.

Combined self-regulating and skid-correcting devices do not prevent the wheels from picking up on greasy rails, so that under such conditions the stopping distance might be longer that it would be with the ordinary brake handled by an experienced driver, owing to the time loss due to the working of the skid corrector. Such devices have not been introduced *in practice.*

To overcome their defects, a French firm Messrs. JOURDAIN-MONNERET, has in-

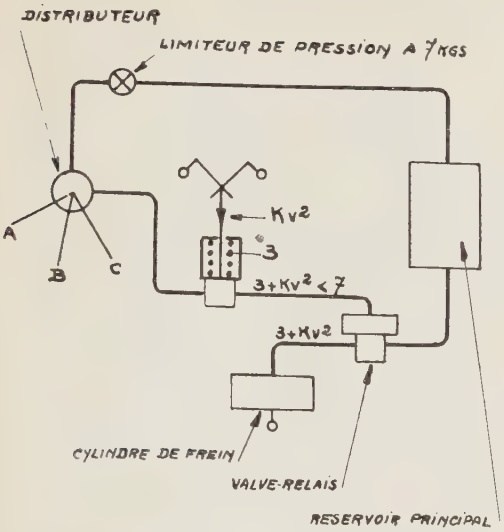


Fig. 37. — Westinghouse straight-acting brake with self-regulator.

Note. — Distributeur = triple valve. — Limiteur de pression... Valve reducing the pressure to 7 kgr. cm². (100 lb./sq. in.). — Cylindre de frein = brake cylinder. — Valve-relais = relay valve. — Réservoir principal = main reservoir.

troduced a new apparatus known as the « auto-decelerator », which works indepently of any self-regulator, and is based on Captain Hallot's patents, which were applied successfully a few years ago on road motor cars. The principle of this system is based on the fact, first mentioned by Metzkow, that the wheels do not pick up instantaneously, but after a period of 3/5 to 4/5 of a second, during which the speed of rotation decreases until it stops. The auto-decelerator works by inertia as soon as the deceleration of the wheel exceeds a fixed value which should be selected as small as possible in order to give the device time to act before the wheels pick up, whilst being made at least equal to the greatest deceleration that can be obtained under the best braking conditions. In practice this value lies between 1.7 and 2 m. (5.6 and 6.6 ft.) per sec. per sec. Every time the wheels tend to pick up, this device, illustrated in figure 38, causes a pressure drop in

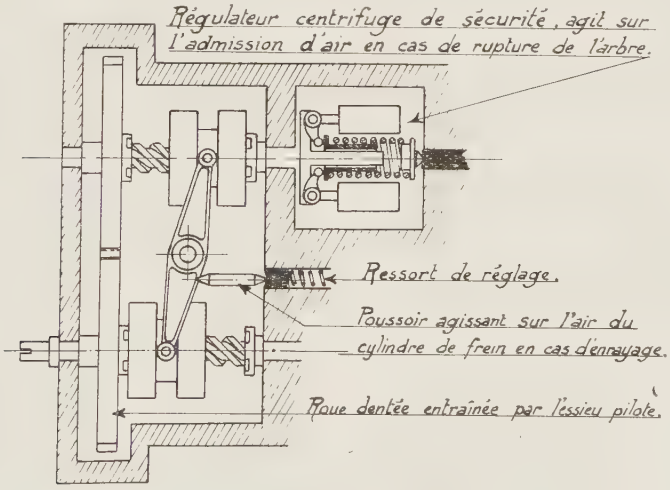

Régulateur centrifuge de sécurité, agit sur l'admission d'air en cas de rupture de l'arbre.
Ressort de réglage.
Poussoir agissant sur l'air du cylindre de frein en cas d'enrayage.
Roue dentée entraînée par l'essieu pilote.

Fig. 38. — Diagram showing the principle on which the J.M. self-decelerator is based.

Explanation of French terms:

Régulateur centrifuge = safety centrifugal regulator which acts on the air admission if the shaft breaks. — Ressort de réglage = adjusting spring. — Poussoir agissant... = push piece acting on the brake cylinder air if the wheels pick up. — Roue dentée... = gear wheel driven by pilot axle.

the brake cylinder, restores the pressure as soon as the deceleration is below the critical value. This apparatus has been applied to a RENAULT bogie railcar with very good results. During tests on a wet rail, without sanding, average stopping distances of 350 m. from 100 km. (1 150 ft. from 62 miles an hour) were made — almost as good as on dry rails (300 m. from 100 km. (984 ft. from 62 miles an hour). As a matter of information we give in figure 39 a diagram of the brake cylinder pressures.

It appears that the question of braking up to the adhesive limits, whatever the state of the rail, will thus be solved in

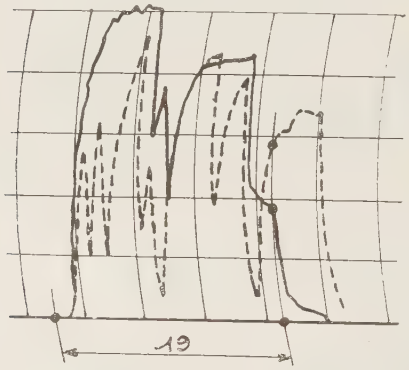


Fig. 39. — Diagram showing the pressure variations in the brake cylinder during a brake application (RENAULT railcar equipped with J.M. self-decelerator).

———— motor bogie.
- - - - - - - - carrying bogie.

Initial speed : 103 km. (64 miles) p. h. — Braking distance : 300 m. (984').
Deceleration : 1.37 m. (4.5') per sec. per sec.

the near future. The fact should not be ignored, however, that these apparatus are rather delicate and complicated, and will probally require very careful and frequent attention to maintain them in good working order. They will probably not come into general use for some time yet.

3. N. R. *Brake of the French State Railways.*

Mr. NICOLET, Assistant Chief Mechanica Engineer of the French State Rys., in collaboration with Mr. ROUSSELET, Controller of the Railcar Service, has designed a new brake system called the « N. R. self-regulated brake », for which the FRENCH STATE Railways took out a patent. This brake makes use of the fact that the coefficients of friction of cast iron and asbestos on steel vary in inverse proportion to the coefficient of adhesion of the wheel to the rail.

The first N. R. brake designed on this principle incorporates double articulated brake blocks, giving four blocks per wheel, two of cast iron and two of asbestos composition. The latter are fitted above the former to prevent them being affected by water from a wet rail, such water being removed by the cast iron block.

The levers applying these blocks (leverage about 3 to 1) (fig. 40) are so designed that a constant brake application gives the maximum possible braking without picking up the wheels, compatible with the adhesion at the highest vehicle speed and the minimum stopping brake power. In the case of intermediate speeds, the retardation curve which is a little more concave than the adhesion curve, as shown by figure 41, always remains below the latter and even very close to it.

In order to also take the variation of the adhesion relatively to the condition of the rail into account, a two-position pressure reducing valve is provided, so that different air pressures can be used according as the rail is wet or dry.

A RENAULT bogie rail motor car, originally braked with two blocks per wheel, was equipped subsequently with this type of brake ; the tests before and after the application gave the following stopping distances :

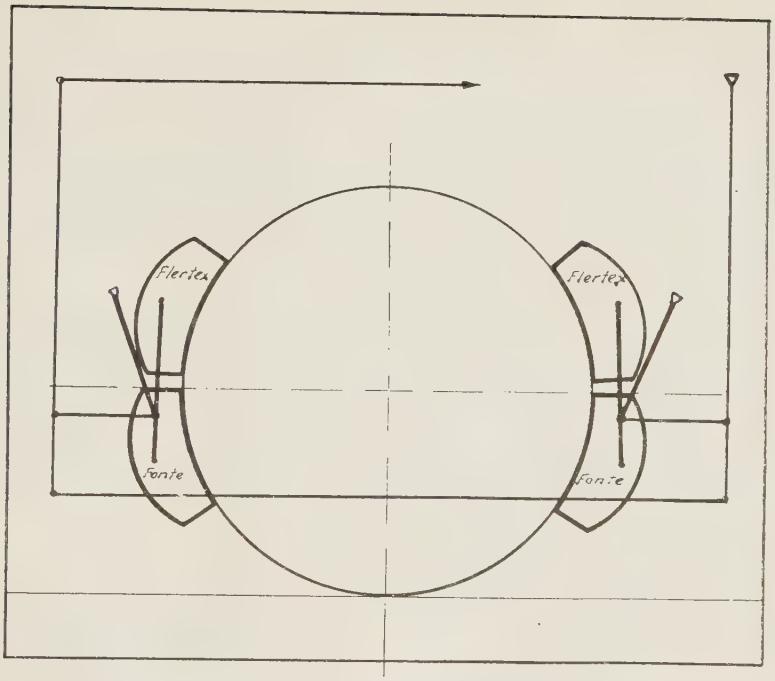


Fig. 40. — Arrangement of brake blocks with the N.R. brake.
Note. — Fonte = cast iron.

	With N. R. brake.	Decelerations.
Dry rail	200 m. from 80 km./h. *(656′ from 50 m.p.h.).*	1.45 m. *(4.75′)* per sec. per sec.
	280 m. from 100 km./h. *(922′ from 62 m.p.h.).*	1.40 m. *(4.60′)* per sec. per sec.
	385 m. from 115 km./h. *(263′ from 71.5 m.p.h.).*	1.37 m. *(4.50′)* per sec. per sec.
Wet rail	360 m. from 102 km./h. *(1 180′ from 63.4 m.p.h.).*	1.14 m. *(3.62′)* per sec. per sec.
	210 m. from 80 km./h. *(689′ from 50 m.p.h.).*	1.20 m. *(3.94′)* per sec. per sec.
	With ordinary brake.	
	340 m. from 100 km./h. *(1 115′ from 62 m.p.h.).*	1.17 m. *(3.83′)* per sec. per sec.
	430 m. from 110 km./h. *(1 410′ from 68.3 m.p.h.).*	1.14 m. *(3.62′)* per sec. per sec.

The values of these first results have been confirmed by a number of tests, and the State Railways have decided to try this brake on a larger scale in actual service. To begin with, 10 Renault bogie railcars of the same type and afterwards a number of other types of railcars already equipped with a self-regulating brake are to be equipped, so that the two systems can be properly compared.

II. — Emergency brakes. — Electro-magnetic brake.

When considering emergency brakes other than the direct and automatic compressed-air service brakes, the evolution of the electro-magnetic brake must be noted. This brake has been fitted to more than half the French railcars ; the type used has two rigid two-pole shoes. As this arrangement caused some trouble

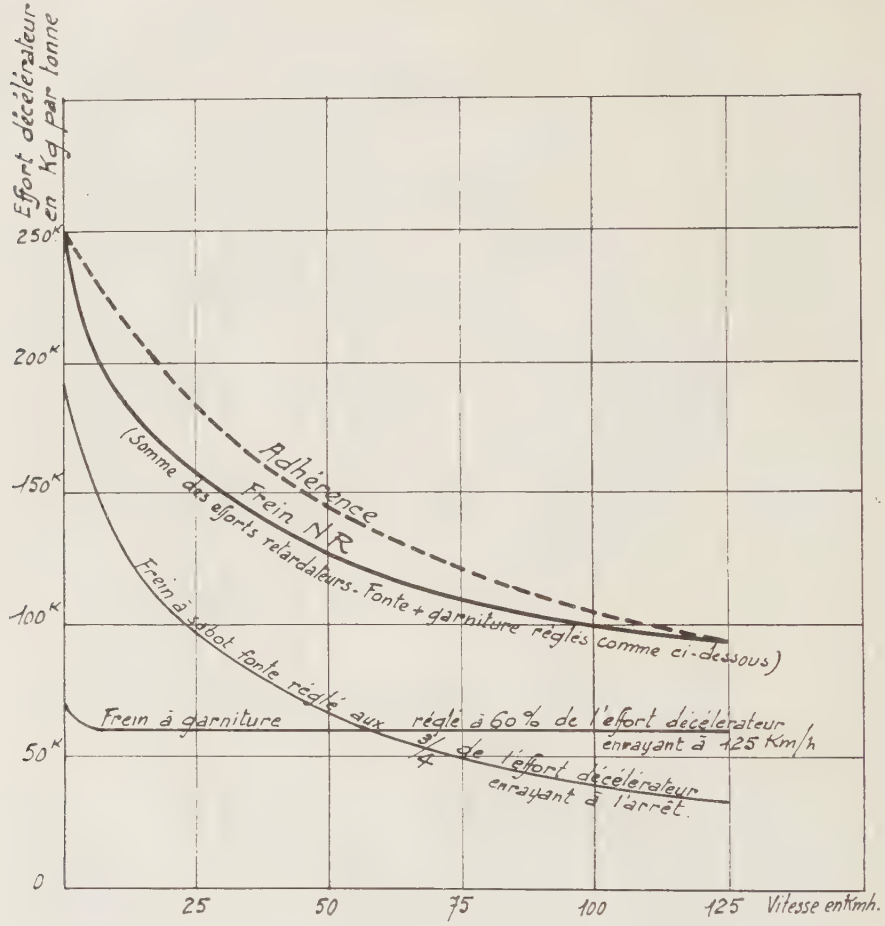


Fig. 41. — Braking curves with the N.R. brake.

Explanation of French terms:

Effort décélérateur = decelerating effort. — Adhérence = adhesion. — Frein NR (somme des efforts...) = NR brake; total of decelerating forces: cast iron + lining adjusted as below. — Frein à sabot... = brake with cast iron block adjusted to 3/4 of the decelerating effort, making the wheels pick up at the end of application. — Frein à garniture... = brake with lining, adjusted to 60 % of the decelerating effort, making the wheels pick up at 125 km. (77.7 miles) an hour.

first noticed in 1935 (blue spots on the rails and induced currents apt to interfere with the track circuits), the French Railways strictly limited its use to emergency cases.

Since that period the JOURDAIN-MONNERET Company has been working in collaboration with the French Railways to eliminate these defects, and many trials have been carried out with the result that:

— the blue spots have been eliminated by using articulated brake shoes distributing the pressure more evenly on the rail;

— the induced currents due to losses

of magnetic flux have been reduced by multiplying the number of the poles of the shoes (brake with four-pole shoes) intended to compensate the losses of flux automatically.

This method has produced appreciable improvements which were insufficient, however, to permit the electro-magnetic brake being used currently on lines equipped with automatic block signalling.

At the present time, the investigations are being continued and tests will be made in the near future with new four-pole articulated shoes, one section of the shoes being replaced by Ferodo linings in order to improve the coefficient of friction and at the same time reduce the induced current without any loss of efficiency.

In countries of Western Europe other than France, electro-magnetic brakes have not come into general use.

III. — Hand-operated stand-by brakes.

Stand-by brakes have not been developed in recent years and their function, in view of the improvements in the service brakes, is becoming limited to holding the vehicle stationary. Usually separate rigging is not provided, and the brake is applied by a hand wheel and screw operating the rigging on only one of the bogies for simplicity. A test recently made on a Renault bogie railcar should be noted. In this case the stand-by brake is applied by Lockheed oil transmission acting on the rigging of both bogies, without excessive complication.

IV. — Slowing-down brakes.

The P. L. M. began trials in 1936, on an articulated s. o. m. u. a. railcar, of a new brake known as « frein de ralentissement » (slowing-down brake), not intended to stop, but to slow down the vehicles quickly and progressively before arriving at stations where they are then stopped by the service brake, or to keep down the speed on long gradients.

This brake, invented by Mr. Sarrazin and known as the Safe-Somua electro-dynamic brake or the eddy-current brake, consists of an iron disk secured to each axle to be braked and revolving in an electro-magnetic field set up by electro-magnets fed by a battery of accumulators; the braking force is regulated by varying the excitation of the electro-magnets.

On a 1 in 40 down gradient, this brake, mounted on two axles carrying a total weight of 24 tons reduced the speed of the 42-ton Somua railcar from 70 to 37 km. (43.5 to 23 miles) an hour in two minutes, and held it at this speed for several kilometres in spite of the disks becoming red hot.

The principal advantage expected from this type of brake is its lower maintenance cost as compared with friction service brakes, which it will then be possible to husband. In any case, its use on certain stock with not too well designed drum brakes has appreciably lengthened the life of the linings.

The same Railway intends to test, on 12 Berliet diesel-electric railcars under construction, a new type of slowing-down brake, known as the rheostatic brake which, according to a well-known principle, uses the traction motors as generators, the electro-motive force developed being opposed to that of the main generators through resistances.

V. — Results. — Summary.

The accompanying figures show the results of trials, for a few railcar types and various brake designs, on the level at different speeds.

Close investigations carried out in recent years in many countries, especially in France, in connection with the question of braking railcars show that shorter stopping distances are to be expected in the future. Much progress has been made recently, especially by improving the drum brakes, by using self-regulating brakes in conjunction with

shoes having very high braking coefficients at high speeds or by the combined use on one and the same vehicle of the different frictional properties of cast iron and asbestos blocks or linings. These improvements ultimately provide higher average decelerations during emergency applications, decelerations which, with the new devices used, are never under 1 m. (3.3 ft.) per sec. per sec. on greasy rails and can be as high as 1.5 m. (4.9 ft.) per sec. per sec. on dry rails, whereas with the ordinary air brake, decelerations of 1 to 1.2 m. (3.3 to 3.9 ft.) per sec. per sec. on a good rail are about the best to be expected.

* * *

To end this chapter, the above figures may be compared with those obtained with high-speed diesel electric trains in America. The problem of regulating the brake power has been studied very closely in the U. S. A., and the result is the self-regulator known as the « Decelakron ».

Unlike the European self-regulating apparatus, this device does not alter the brake cylinder pressure proportionally to the vehicle speed, but in proportion to the rate of decelaration. As a matter of fact it is made up of a pendulum, or a free carriage, which moves by inertia. The results of the trials carried out, as published in the American technical press, showed decelerations of 1.20 m. (3.94 ft.) per sec. per sec. as a maximum.

Running gear.

The increase in the speed of railcars and the demand for comfort at high speeds have led the builders to devote special care to the riding qualities.

Some high-speed railcar builders have retained the railway type of bogie with axle-box guides, but experience has shown the importance of keeping down the play in the running gear and the necessity for connecting the body to the bogie in such a way as to provide some adjustable lateral displacement. As the cost of taking up play frequently is considerable, endeavours continue to be made to lengthen the period between such operations.

Good results have been obtained by making the guides of harder metal and in some cases by fitting central automatic lubrication.

Other builders have preferred to develop special designs without axle-box guides. The BUGATTI articuled bogies (fig. 42) are quite different from any others in that, in spite of their small wheel diameter (720 mm. = 2'4 3/8") they run smoothly over points and crossings, owing to the use of 4 axles, which reduce the rail shocks to a minimum, when running over such appliances.

Even at high speeds, the side thrust of the wheels on the rails is extremely low (one ton at most) as revealed by the tests with quartz detectors.

The articulated bogies common to two bodies appear to have given no trouble ; some Railways, however, have found that above 120 km. (75 miles) an hour there is a tendency of the joint bogie to take up and retain some hunting motion.

Wheels turning freely about fixed axles are used on some railcars (MICHELINE, BUGATTI) ; the two outer axles of the BUGATTI bogies are fixed. These axles behave very well in service and such design seems to make curve negotiation easier at high speed.

The construction can be lightened by the use of fixed axles, as the latter are not subject to alternated bending and consequently the weight of the unsprung revolving parts can be reduced.

However, this arrangement complicates the problem of short-circuiting the track circuits, as it is more difficult to ensure a low and more or less constant ohmic resistance between the two wheels.

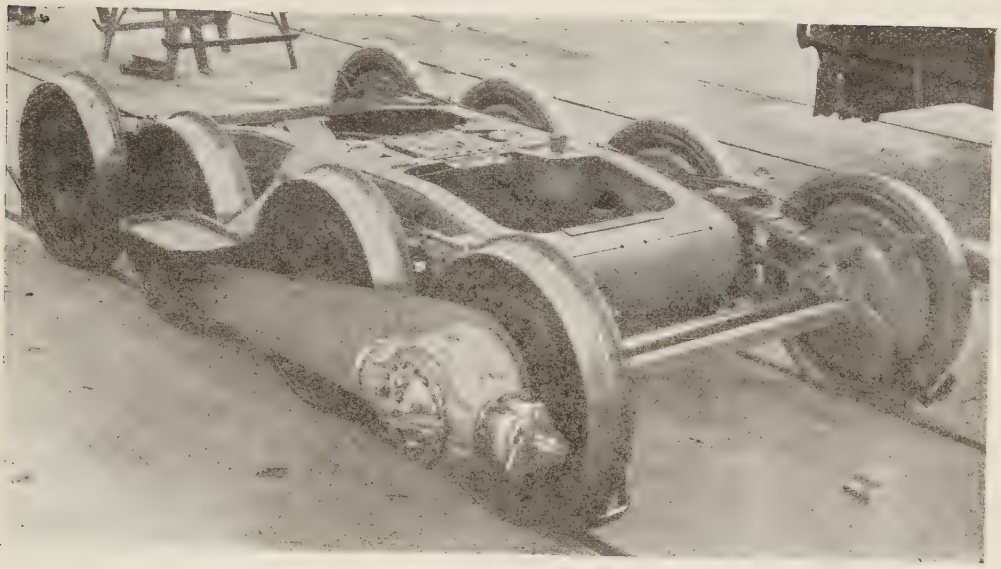


Fig. 42. — Bogie of 400-H.P. Bugatti railcars.

A certain number of railcars have one-piece wheels which have the following advantages .

1. *Lightness.* — All things being equal, there is a reduction in the unsprung weight which makes for comfort and reduces the inertia of the revolving masses, so improving to a slight extent the starting acceleration ;

2. *Safety.* — There is no fear of the tyres coming off.

In this case too, special steels should be used so as to lengthen the tyre re-turning intervals and save the costly lifting operations.

The one-piece wheels of the Renault railcar wear 0.8 to 1.5 mm. (0.031″ to 0.059″) per 60 000 km. (37 300 miles) and are turned up every 150 000 km. (93 000 miles). Owing to the hardness of the metal, special tools and grinders are required.

The contours of the little coned tyres applied to wheels on fixed axles reduce as a rule the hunting movements of bodies suspended on bogies of fairly different designs (Bugatti, Franco-Belge, etc.).

The top of the rails being inclined 1 in 20, tyres turned to a flatter cone wear quickly, especially when braked with standard blocks. They gradually become 1 in 20 after 20 000 km. (12 400 miles) when coned 1 in 40, and after 35 000 km. (21 750 miles) when turned cylindrical, in the case of G or GG steel wheels. In addition the metal is rolled over horizontally and forms a burr on the side of the tyre opposite the flange.

For this reason some Railways (French Nord on Franco-Belge railcars) use chrome-molybdenum cylindrical tyres; the special metal has to be especially carefully manufactured. The tyres have to be carefully machined before shrinking on to ensure they bed down properly on the centres. Moreover, special equipment (tools) is required owing to the hardness of the steel.

By such means the wear has been reduced, and the tyre re-turning intervals

Fig. 43. — MICHELINE triplet railcar of the French State Rys.

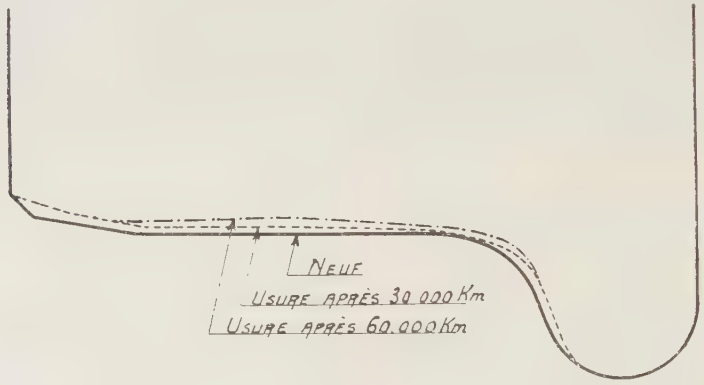


Fig. 44. — Tyre wear on T.A.R. FRANCO-BELGE railcars of the French Nord Ry.
Note. — Neuf = new. — Usure après 30 000 (60 000) km. = wear after 18 600 (37 500) miles have been run.

have been increased on the French Nord to 60 000 km. (37 300 miles).

The pneumatic tyres fitted on the MICHELINES at the same time provide the rolling surface and act as shock absorbers, and they have been improved considerably during the last two years.

The shape of the air tube and the ring fitted to limit the drop of the tyre in the event of deflation have been altered, and the behaviour in service of such parts has considerably improved.

In the case of the old tyres, the maximum load allowed per wheel was 800 kgr. (1 760 lb.) and it could not be exceeded. In spite of this, the number of burst tyres reached 1 in 7 000 km. (4 350 miles) ; since the introduction of the new air tubes and thanks to the progress made in manufacturing the covers, the weight per wheel has been increased to 1 100 kgr. (2 420 lb.), with a tolerance of 100 kgr. (220 lb.), and the number of bursts at the present time is only 1 per 70 000 km. (43 500 miles), although the number of pairs of wheels per coach has been increased from 6 to 8.

A number of Railways have succeeded in braking the transverse movements of the body relatively to the bogie, by using

shock absorbers ; the tests have not yet given any very definite results.

A test was made on a Bugatti railcar with a shock absorber braking the movement of rotation of the bogies ; the transverse accelerations of the body ends were damped out when the tyres were coned 1 in 20 and aggravated when coned 1 in 40.

Some Railways are supporting the bodies of their high-speed railcars on a transverse triangular rod.

This arrangement reduces the magnitude of the horizontal oscillation when running unto curves or turn-outs.

An arrangement that has shown itself effective is to carry part of the weight of the body on the bogie side friction blocks (Micheline, Standard, Renault, etc.).

* * *

CHAPTER V.

Safety and comfort.

Safety.

We considered in the first chapter some of the problems affecting safety. short-circuiting, emergency stops, warning at level crossings, fire protection ; the last problem should be considered extremely important, and we feel that it requires special attention.

Experience has shown that even the smallest fire in a railcar can sometimes become extremely serious if suitable steps are not taken at once.

It is, therefore, interesting to consider how a fire can occur in a railcar and the methods adopted by the Railways to prevent it having serious consequences.

We will describe first of all the conditions under which serious fires on railcars have occurred since 1933, and their results.

We will then call attention to the steps taken against the extension of fires before the 1935 Meeting (principally on petrol-engined railcars, the first to be put into use), and will develop the steps taken since this Meeting (principally on diesel railcars).

Finally, while examining the various fire-extinguishing methods, we will investigate the advantages, drawbacks and the optimum conditions of use of the different products used in the fire-extinguishing apparatus.

1. Conditions under which serious fires broke out on railcars since 1933 and the consequences thereof.

Serious fires have not been reported by any Administration except the French Main-Line Railways. These railways since 1933 have had several fire outbreaks, three on petrol railcars, and seven on diesel railcars. The causes and consequences have been the following.

Petrol railcars.

The three fires which resulted in the total destruction of the body, and in one case the death of a man, were caused in two cases by insignificant incidents (breaking of a petrol pipe, the overflowing of a petrol tank, followed by the petrol vapours coming into contact with the flame of a naked flame lamp) ; the third was caused by a derailment which would not have had serious consequences if all the proper precautions had been taken (cutting off the ignition for example).

Diesel railcars.

The *causes* of the seven fires can in fact be reduced to two :

1. broken engine connecting rod, accompanied by the crank case being damaged, which resulted in the fuel oil and lubricating oil released taking fire, either by coming into contact with very hot parts, or by short circuits due to the initial defects mentioned above, or through contact with incandescent

sparks (when a locomotive was hauling a railcar with the above defects) : three cases ;

2. short-circuit in the motor bogie or the engine compartment, through defects in the electric cables or their connections : four cases.

The *consequences* of these fires were as follows :

— in one case very serious damage to the engine compartment, the fire having otherwise been checked by the fire-proof partition behind this compartment ;

— in a second case, very serious damage of the engine compartment with damage to the adjacent compartment ;

— in the other cases complete or almost complete destruction of the body of the rail motor car.

2. Steps taken previous to 1935, chiefly on petrol railcars, to prevent fire spreading.

The accidents reported in paragraph 1 above led the French main line Railways to consider additional safety measures. The petrol railcars having been the first to give rise to accidents, a very careful study was made and showed that it was necessary to take the following steps to do away with the causes of fires or to prevent them from spreading :

(a) Drawing up suitable instructions on the safety precautions to be taken against fire when driving and repairing railcars and when anything goes wrong ;

(b) Use of automatic devices preventing the petrol tanks on railcars being filled too high ;

(c) Protection of the petrol tanks by a plastic fire-proof case and installing them as far away as possible from likely causes of fire ;

(d) Feeding the engines by flexible pipes unaffected by vibrations, instead of by rigid pipes ;

(e) Fitting the petrol tanks as far as possible at a lower level than the carburettors ;

(f) Use of decanting tanks, to allow any impurities in the petrol to settle out and also prevent back firing to the carburettors ;

(g) Suitable arrangement of the auxiliary equipment (carburettors, pipes, etc.) so that they cannot be damaged through a broken rod ;

(h) Use of bars wrapped in insulating material for carrying the ignition wires to the engine and use of safety clips for connecting sparking plugs to the wires, in order to prevent sparking due to broken ignition wires ;

(i) Fitting snifting valves inside the engines ;

(j) Providing a fire-proof partition behind the engine ;

(k) Providing in a convenient position for the driver, trainmen, and passengers, extinguishers, one in each driver's compartment (carbonic foam, methyl bromide, carbonic acid, for use inside the vehicle, and carbon tetrachloride for use outside).

The adoption of such measures should prevent the occurrence of any such serious accidents on petrol railcars as those mentioned in paragraph 1 above.

The use of some of these measures (instructions, extinguishers, etc.) has improved the protection of the earlier diesel railcars in service.

3. Steps taken since 1935, principally on diesel railcars, to prevent fires spreading.

As soon as the first diesel railcars were put into service, it became evident that the use of heavy oil instead of petrol was far from doing away with the fire danger.

Fires are apt to break out like when petrol is used, for causes independent of the type of fuel used (short circuits, heating of the electrical and mechanical

parts, sparks from the brake shoes, carelessness of the passengers or maintenance staff, etc.), but it was found, at least on the French main-line Railways, that some cases of fires breaking out or spreading were due to the fuel itself, which has the following drawbacks :

— the gas-oil from a leak adheres to the details of the engine, the bogie and the underside of the body, and impregnates any spongy matters such as the insulating materials (when a fire began these materials fed the fire in the way of a lamp wick);

— destruction of the rubber insulation of the electric cables by the fuel oil, thereby increasing the risk of short circuits;

— high temperatures sometimes reached in the silencers and exhaust pipes;

— danger of fire developing in the local feed tanks located close to the engines.

In addition, boilers fired by fuel oil (heating boilers in certain diesel railcars) are also a cause of fire owing to the risk of the burners not working properly.

The above considerations, as proved by many incidents, made it necessary to take very careful precautions against fire.

Below we will consider the steps taken in this connection by the different Railways, first of all as preventive measures, and then to actually fight a fire that has just broken out.

Preventive measures.

These are of three kinds :

(A) Use of incombustible or fire-proofed materials;

(B) Arranging the details of the equipment, heat engines, mechanical or electrical equipment, so as to reduce the fire risk, or the development of a fire due to these equipments;

(C) Special precautions to be taken in the depots or repair shops.

(A) *Incombustible or fire-proofed materials.*

These materials are not in general use.

Their value has, however, been shown on the French main-line Railways during a fire in an engine room which tended to spread to the body of the railcar; the material lining out the adjacent compartment contributed to check the fire.

In addition the French Railways have undertaken systematic tests on materials, made fire-proof recently or some time ago, in order to ascertain the conditions to be complied with when fire-proofing materials.

(B) *Heat engines, mechanical and electrical equipment.*

Many Railways report that they take care to prevent combustible materials being placed near hot parts of the engines or boilers (French main-lines Rys. and London North Eastern) and that they provide a special valve to cut off the gas-oil tanks (French main-line Rys. and Belgian National Rys. Co.).

In addition the French Railways have been led to take the following supplementary steps :

(*a*) in the engine compartment, besides doing away with wood floors, which are known to be dangerous, eliminating heat insulating materials of a combustible or spongy nature;

(*b*) protection of the exhaust pipes against leaks of liquid fuel;

(*c*) reducing the local feed tanks of the engines to the smallest size and strengthening them (discontinuing any tin soldering, for example);

(*d*) collecting the leakages of fuel oil or other oils in containers placed below the engine;

(*e*) separating the ventilation of the engine compartment from that of the passenger compartments, and hereby

completing the effectiveness of the fire-proof partition;

(*f*) improving the insulation of the electric cables and their connections with the parts they control, and attempting to find a suitable method of protecting these cables from being attacked by the fuel oil;

(*h*) maintaining the frames of the bogies and the lower parts of the carriages perfectly clean, by cleaning them at regular intervals (every 15 days to a month according to the work done by the rail-cars, usually by means of hot water under pressure) ;

(*i*) designing and testing on diesel railcars an automatic electro-magnetic valve intended to cut off the fuel oil main tanks and local feed tanks if fire breaks out.

Some other Railways, in particular the Italian State Rys., have considered it desirable to take precautions of the same kind.

(C) *Precautions to be taken in the sheds or repair shops.*

To prevent fires breaking out the following recommendations can be followed usefully :

— not to leave rags about the engines or bogies;

— not to use open-flame burners (electric or oxy-acetylene welding, oil burners, etc.) without first carefully cleaning the parts of the railcar to be dealt with and removing all combustible matters;

— to prevent short circuits in the equipment, being caused by the tool equipment used.

Steps taken to put out fires.

Detection of fires.

The Railways consulted report that they do not use fire detectors (except for some detectors with fusible alloys or cartridges fitted to the small extinguishers to put out carburettor fires used on the French main-line Rys.). The Italian State Rys. use fusible plugs placed on the carburettors, which cut off the petrol supply in the event of a back fire.

The French main-line Rys. are in addition carrying out trials with fire detectors which in the event of a fire breaking out give either a light or audible signal, or release a powerful fire extinguisher.

Fire extinguishers.

The Railways consulted fit all their railcars with portable fire extinguishers of one or other of the following types : methyl bromide (French main-line Rys.), carbonic acid foam (French main-line Rys., Belgian National Rys. Co., Netherlands Rys., Italian State Rys.), or carbonic acid snow (French main-line Rys., Belgian Nat. Rys. Co.), carbon tetrachloride (French Nord, Netherlands Rys., Great Western Ry.), or fire-proofing liquid (London & North Eastern Ry.). In addition the French main-line Rys. use very finely pulverised water for certain purposes (putting out the coke in heating boiler fireboxes, for example).

These extinguishers are installed in the railcars either in the driver's compartments (French Rys.) or close to the engine compartment near the entrance doors (Belgian National Rys. Co. and French main-line Rys., for example).

In addition the French main-line Rys. fit such extinguishers in the trailers, and in certain railcars of high-power, or fitted with multiple engines, fixed or removable extinguishers of much greater capacity than the usual portable ones are provided; these special extinguishers are connected either to fixed pipes with suitable hose, or to a nozzle at the end of a hose (this hose and nozzle make it possible to get at fires in otherwise inaccessible places).

An example of a widely used equipment with a water hose nozzle is the methyl bromide extinguisher of 2 to 4 litres (3.5 to 7 pints) capacity with a nozzle having a hand-operated valve; the valve makes it possible to shut off momentarily the discharge of the bromide vapour and save it, in case the fire breaks out again.

It might be interesting to ascertain the minimum fire extinguishing capacity of the extinguishers fitted in railcars of the different kinds.

To do this the French main-line Rys. have taken into account to some extent the floor area of the vehicle, the power and number of the engines, the nature of the transmission (mechanical or electric), and the presence of heating boilers.

Each type of railcars was thus given a certain minimum number of extinguishers (4 to 14), the value of the unit having been arbitrarily fixed at 0.5 litres (0.8 pint) of methyl bromide, 50 litres (11 Br. gall.) of carbonic foam, 5 kgr. (11 lb.) of carbonic acid, and one litre (1.75 pint) of carbon tetrachloride.

4. Advantages and drawbacks of the various products employed in fire extinguishers and best methods of using them.

Each of the products used in the extinguishers has advantages and drawbacks, and can be used to the best advantage according to the replies of the Railways consulted.

(a) Methyl bromide.

Advantages. — This is a refrigerant and a non-conductor of electricity; it makes the surrounding atmosphere non-carburating : it has great extinguishing power for a small volume (twice that of carbon tetrachloride); it is not toxic when nearly pure, under reserve of course that the concentration of the vapour is not too strong; it leaves no trace on parts or objects upon which it is sprayed ; it can be preserved indefinitely in sealed glass bulbs (tests are being carried out to see if this can also be said of metal containers, when properly prepared); it only freezes up below — 90° C. (— 130° F.) approx.

Drawbacks. — The cost is high, as is that of the containers, except when made of metal; it is very volatile, and is difficult to put into containers; it boils at 4° C. (39.2° F.) at atmospheric pressure; it cannot be volatilised at low temperatures except by means of an auxiliary air pressure or of compressed nitrogen; it is not very efficient in the case of fire from surfaces raised to high temperature (coke fire, for example).

Best conditions for using it. — It is employed in the early stages in the form of a commercially pure methyl bromide vapour (with about 4 % of impurities, but without carbon tetrachloride) in enclosed places, on smooth surfaces which are not too hot; the operator should get as near to the fire as he possibly can and prevent the heat reaching him by slight preliminary spraying of the bromide which forms a protective screen of cold air.

(b) Carbonic acid foam.

Advantages. — It has a great resistance to heat, the layer of foam almost completely prevents any risk of the fire breaking out again (durable effect with a thick foam which adheres perfectly on surfaces of all kinds), the apparatus and recharges cost relatively little, and recharging is easy; there is a special foam for putting out fires of alcohol or alcohol-petrol mixtures.

Drawbacks. — Owing to its small electric rigidity, the foam cannot be used for putting out fires of electrical origin when the voltage exceeds about 125 V. (it is not suitable consequently for electrified lines and for railcars with electric drive); the charges have to be

renewed at intervals; the foam being dirty, its use is inconvenient for putting out engine fires, as the engines have to be completely cleaned each time a fire is put out; after a time the foam attacks woven materials; the apparatus of over 100 litres (22 Br. gall.) of foam capacity are very bulky.

Best conditions of use. — It can be used in enclosed places or open places on any surfaces; it is specially recommended for putting out layers of liquid on fire; the foam is the most satisfactory complement of methyl bromide.

(c) Carbonic acid (produced by sudden expansion of carbonic snow).

Advantages. — It is not a conductor of electricity, more cooling than methyl bromide, and makes like the latter, though to a lesser degree,the surrounding atmosphere non-carburating, and has a more powerful action than the bromide on account of the wind which accompanies the jet of snowy fog; it is not poisonous and in no way damages the apparatus and woven materials.

Drawbacks. — The apparatus for carbonic acid or carbonic foam are heavy, expensive and bulky.

Best conditions of use. — It is to be used in closed places or open places on relatively smooth surfaces, in the form of fog or snow.

(d) Carbon tetrachloride.

Advantages. — It is much cheaper than methyl bromide (see above).

Drawbacks. — It cannot be used in small enclosed places as it is poisonous (these effects sometimes being delayed); the fumes which come off by contact between the tetrachloride and the flames hide the seat of the fire and interferes with the operator; its extinguishing power is lower than that of methyl bromide (see above).

Best conditions of use. — In the open, as a spray preferably, or as a jet breaking up on solid surfaces so as to cause it to be pulverised (in this case the jet is directed at the base of the flames).

* * *

Fire-proofing liquids (mixture of carbonic acid and water) have much less power than the four products mentioned above and have the drawbacks of conducting electricity and spreading the burning liquid over the ground.

Very finely pulverised water which is hardly a conductor of electricity and has a very high extinguishing power on account of its instantaneous evaporation, can be considered for putting out certain fires in railcars (coke fires, for example).

* * *

Comfort.

We thought it necessary to give here some ideas on two important factors regarding comfort in rail motor cars : sound proofing and air conditioning, which it must be admitted have been neglected up to the present.

Sound-proofing railcars.

The sound-proofing of railcars is a problem which has been given the more attention in recent years that higher speeds, the substitution of metal for wood, for safety reasons, and of smooth simply painted surfaces for upholstered panelling, for reasons of economy, maintenance and aesthetics, the appearance of the power plant and accessories on the vehicle carrying the passenger itself, were all causes of increased noise.

Measuring the noise in a railcar or more generally in a railway carriage is a delicate operation, in view of the complexity of the sound waves encoun-

tered. The human ear is only sensitive to a certain frequency : for example, frequencies of 20 periods per second are not audible; between 20 and 2 000 periods, the ability to hear increases (i.e. the source of energy diminishes) and then declines; at about 16 000 periods per sec. it ceases; in practice attempts should be made to damp out noises of 50 to 10 000 periods per sec.

As we know the ear is sensitive to the variation of the logarithm of the variation of sound energy (Fechner's law); for example, the sensation is the same when the energy changes from 1 to 2, or from 1 000 to 2 000.

Two methods and consequently two classes of instruments are available for measuring noise : the subjective method consisting in measuring the intensity of the sensation produced by the sound waves, and the objective method consisting in measuring the energy of these waves.

1. Subjective method.

(a) Equality method — the principle of which is for the ear to compare the noise to be measured and that of a pure sound of an adjustable intensity given by a telephone receiver. This method is used in the Barkhausen tube; a vibrator adjusted for 800 periods per second, inserted in series with a battery in the primary winding of a transformer induces in the secondary a current of 800 periods per sec., rich in harmonics. At the terminals of the secondary there is a potentiometer graduated in phones feeding a telephone receiver.

(b) Mask method — by which it is possible to measure the intensity of a noise by its masking effect on one or several reference sounds. Its advantage over the Barkhausen method is that the ear appreciates with great precision the moment at which the reference sound ceases to be audible. The audiometer of the L.M.T. Company, which has been used for some months by several Railways, is based on this principle.

It should be noted that the mask method and the equality method do not give comparable results. On the other hand, with each of the two methods the results obtained vary slightly with different experimenters.

2. Objective method.

The equipment used includes in principle a microphone, an amplifier, and a measuring instrument (millivoltmeter, milliammeter with rectifier, thermocouple). These devices are provided with filters, the curves of which follow the form of some of *Kingsbury*'s curves (case of the *Kagan* apparatus), or filters making it possible to measure the actual intensity of the sound in the frequency bands, octave by octave (case of the L.M.T. Company's apparatus used by the French State Rys. or the *Zand* instrument used by the Air Ministry and the Air-France Company).

System of acoustic units. — The different units used are the Decibel, the Decinaper, and the Phone.

(a) Decibel. — The sensation of intensity is expressed by the equation

$$S = 10 \log. \frac{I}{I_0} \text{ decibels,}$$

I and I_0 being the intensity of the sound and the intensity at the beginning of audibility, which comes to

$$S = 20 \log. \frac{p}{p_0} \text{ decibels,}$$

when using the ratio of the pressures.

(b) Decinaper. — The equations defining it use the ratio of the acoustic pressures instead of the ratio of the intensities, and the Naperian logarithms

$$S = 10 \, L \frac{p}{p_0} \text{ decinaper.}$$

(*c*) *Phone.* — Has the same definition as the decibel, but with a different reference level.

Actually, at the present time, the level of audibility taken as the reference level in defining the intensity has not been agreed internationally.

Some years ago the English and American sound engineers adopted as their reference level that corresponding to an actual pressure of 1 millibarye for a sound of 800 to 1 000 p.p.s.

America (American Standards Association) has adopted more recently a reference level which corresponds to a sound intensity equal to 10^{-16} watt radiated through a normal surface of 1 square centimetre at right angles to the direction of propagation

$$p_0 = 0.000207 \sqrt{\frac{H}{76} \times \sqrt{\frac{273}{T}}}$$

Germany has selected a reference level such that an actual sound pressure of 1 dyne/cm^2 corresponds to a level of audibility of 70 db.

To sum up :

$$70 = 20 \log_{10} \frac{}{p_0} \text{ or } p_0 = 0.000316 \text{ barye.}$$

This shows that, before the results can be interpreted, it is necessary to know the bases used by the experimenter.

Let us now see how it is possible to reduce the noises in railcars. It can be said that a compartment is comfortable from the point of view of noise when it is possible for two people to talk without raising their voices; it is admitted that the sound intensity of a conversation is about 50 db.; consequently about 50 db. is the mark we ought to try and reach. At the present time, the noise level in specially conditioned railcars (T.A.R. FRANCO-BELGE) is 60 to 62 db. and frequently reaches 70 to 72 db. In the Michelines it is, of course, lower.

To improve the comfort, first of all the intensity of the sources must be weakened : all play prevented, perfectly rigid assemblies made between partitions, walls, floors, and elimination of vibration of doors, advertising panels, lights, ash-trays, luggage racks, etc.

Dynamos, fans, and air compressors should be specially designed from the point of view of noise.

Moreover, at high speeds the friction of the air on the outside walls produces noises, the intensity of which will be lessened as the streamlining is improved.

After having dealt with most of the sources of noise, the next thing is to prevent their transmission by making the doors, inspection doors and windows perfectly tight, (replacing drop lights by fixed lights saves 6 to 8 db.).

The floor should be given particular care, and suitable combinations of insulating materials or air cells used. Great precautions ought to be taken in the air conditioning plant to prevent transmission of noise from the motors through the air or walls of the ducts.

It is also necessary to take all possible precautions to prevent the transmission of vibrations from the engine and bogies to the walls of the vehicles, by suitably using plastic materials which absorb the vibrations (rubber).

Finally when everything possible has been done to reduce the noise at its sources, or by preventing its transmission by air or through the walls, the interior fittings of the vehicles should have attention and absorbent materials such as hangings (tapestry), cushions, carpets, etc., be used.

Improvements have already been obtained through the first efforts of the Railways and it may be said that the investigations in hand will improve the comfort of the passengers very appreciably.

Air conditioning.

The feeling of well-being the user of railcars should have depends essentially upon the following conditions :

— Regulation of the air temperature in the compartments;

— Frequent renewal of the air;

— Adjustment of its hygrometric condition.

Originally the object of air conditioning was especially to reduce in summer the inside temperature of fast railcars running long distances, such vehicles being generally fitted with fixed lights in order to reduce as far as possible air resistance at high speed.

The different solutions adopted up to the present time to obtain this result consist in fitting portable or fixed fans, the insufficiency of which in practice has been recognised, seeing that these apparatus in fact only stir up the air in the compartment without appreciably reducing the temperature.

In addition, the use of fixed fans did not make it possible to renew the air when standing, especially when the railcars had been standing in the sun, when the inside temperature frequently had reached 32° C. (90° F.) or over, when the passengers were admitted.

A first improvement of these conditions was obtained by the French Nord Ry. on the triple Franco-Belge sets by forcing ice-cooled air in the compartments.

Temperature records taken during the 1935 summer showed that the temperature inside the coaches was reduced some 7° C. (13° F.) in 60 minutes which corresponded to the melting of 150 kgr. (330 lb.) of ice.

This reduction of temperature could not be maintained en route owing to the absence of any refrigerator, the effect of pre-cooling being lost after running one hour.

The builders then endeavoured to obtain cooled air by fitting a self-contained refrigerating set.

The most usual solutions consist in :

— Blowing in air, cooled directly or not, by ice;

— Passing the air through a chamber with a water spray;

— Mechanical cooling by means of a refrigerator with compressor.

At the same time the builders have taken steps to improve the heating, which up to the present was not satisfactory as regards temperature regulation.

It is not sufficient, in fact, to produce hot air by means of any particular system, but it must be properly distributed so as to obtain as uniform a temperature as possible inside the vehicles.

In modern railcars the hot air is as a rule distributed through ducts generally placed near the roof and at floor level.

These ducts can also be used to distribute cooled air during the summer. By using them, ordinary radiators, which are ugly, take up much room, and involve much supervision and constant repair, need not be used.

Below we describe briefly a number of air-conditioning equipments which have been provided in recent railcars :

Triple railcars of the Belgian National Railways Company (fig. 45).

Fresh air from outside is filtered and then passed over a heater. It is then passed through the ducts to diffusers placed under the seats, from which it passes into the compartments.

The used air is sucked up into a duct in the roof from which it escapes to atmosphere.

Thermostats fixed on the inlet suction duct regulate the temperature of the heater.

In summer the outside fresh air, after being filtered, is forced through the top duct and circulated in the opposite direction to the heated air. The used air is drawn out through the diffusers under the seats and exhausted to atmosphere.

These multiple-units are not fitted with any cooling device.

Fig. 45 — BAUME & MARPENT triplet railcar of the Belgian National Rys. Co.

ABJ Renault and 800-H.P. Bugatti rail motor cars of the French State.

The French State Railways as an experiment equipped two of their railcars with air-conditioning plant based on the following principle :

Unlike the usual methods of heating which overcome the cooling effect of the walls by heating the inside of the compartment, the process consists in heating the walls by hot air. The calorific radiation produced is sufficient to ensure the comfort of the passengers, who only breathe fresh air. Automatic regulators keep the resulting temperature at its best value and prevent any extraneous causes affecting it.

(a) *A.B.J. Renault railcars.*

The air for heating and ventilating in winter is drawn in from outside. It is then filtered and passed over a heater kept hot by the exhaust gases and then forced through a main duct placed along the centre line of the ceiling (fig. 46).

Thence it is distributed to the two ends of the railcar by two longitudinal openings between the duct and the roof. It is then collected by lateral ducts fixed above the windows which force it along the vertical walls before being diffused into the coach (fig. 47).

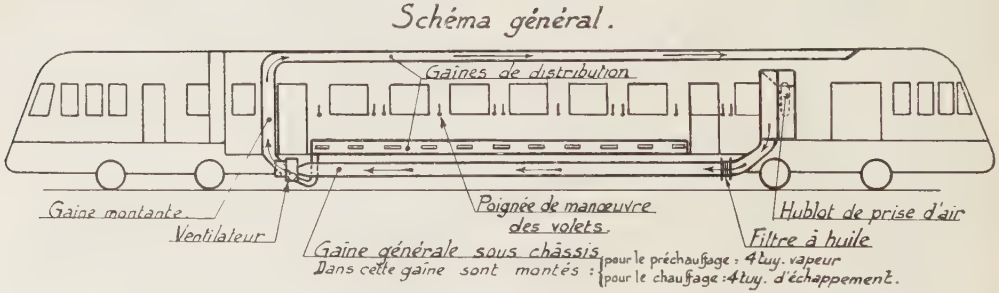


Schéma général.
Gaines de distribution
Gaine montante
Ventilateur
Poignée de manœuvre des volets
Hublot de prise d'air
Filtre à huile
Gaine générale sous châssis
Dans cette gaine sont montés :
pour le préchauffage : 4 tuy. vapeur
pour le chauffage : 4 tuy. d'échappement.

Fig. 46. — Diagram of heating system on RENAULT A.B.J. railcar of the French State Rys.

Explanation of French terms:

Gaines de distribution = distribution ducts. — Gaine montante = ascending duct. — Ventilateur = fan. — Gaine générale... = Main duct under body : in this duct 4 steam pipes (for preheating) and 4 exhaust pipes (for heating) are located. — Filtre à huile = oil filter. — Hublot de prise d'air = air intake.

The floor is heated by hot air forced through a series of ducts about 10 cm. (4″) above the floor.

The temperature is maintained automatically at 20° C. (68° F.), as the exhaust gases can be exhausted to atmosphere as soon as this temperature is reached, and diverted back into the heater if the temperature drops.

In summer, there is simple ventilation, and the passengers can direct the air current at will if they wish to « fan » themselves.

(b) *Bugatti railcar.*

The outside air, after being filtered, is passed over hot water radiators heated by the engine exhaust gases (fig. 48).

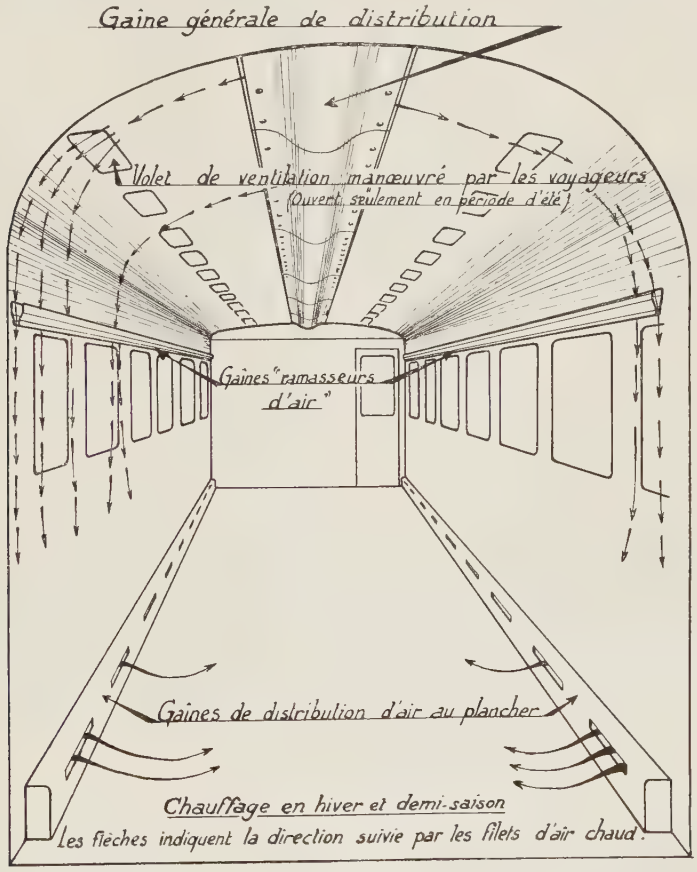

Gaine générale de distribution
Volet de ventilation manœuvré par les voyageurs
(Ouvert seulement en période d'été)
Gaines "ramasseurs d'air"
Gaines de distribution d'air au plancher
Chauffage en hiver et demi-saison
Les flèches indiquent la direction suivie par les filets d'air chaud.

Fig. 47. — Heating system of Renault A.B.J. railcar of the French State Rys.

Explanation of French terms:

Gaine générale de distribution = main distribution duct. — Volet de ventilation... = ventilation shutter operated by passengers (open only in summer). — Gaines « ramasseurs d'air » = air exhauster ducts. — Gaines de distribution d'air au plancher = ducts distributing air at floor level. — Chauffage en hiver et demi-saison. Les flèches... = heating in winter and between seasons; the arrows show the path followed by the warm air fillets.

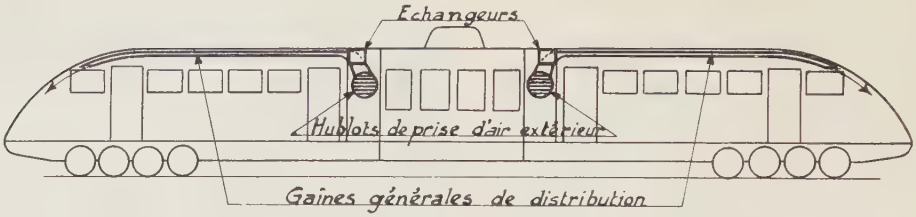


Fig. 48. — Heating system on BUGATTI railcar of the French State Rys.

Note. — Echangeurs = exchangers. — Hublots de prise d'air extérieur = outside air intakes. Gaines générales... = general distribution ducts.

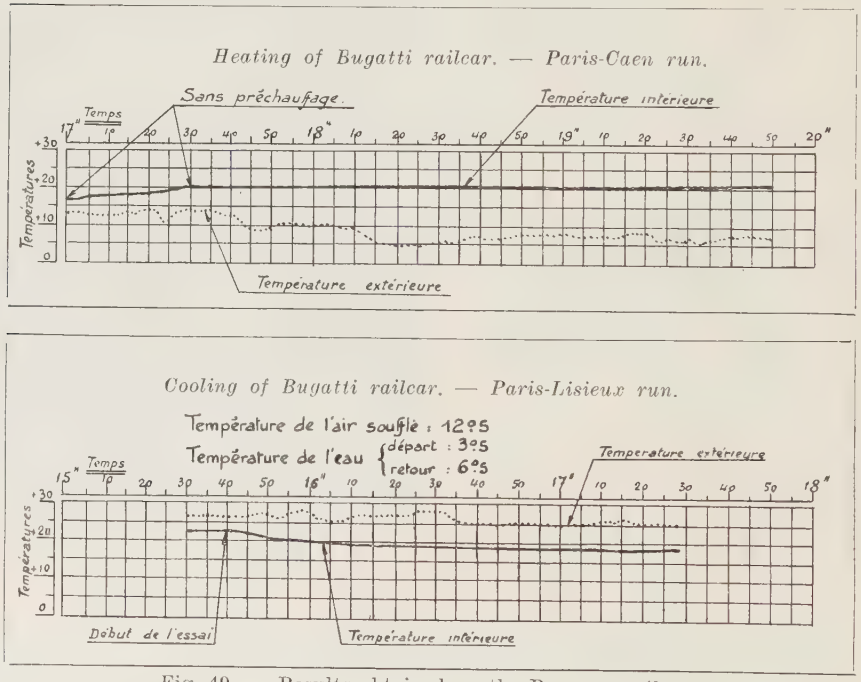


Fig. 49. — Results obtained on the BUGATTI railcar of the French State Rys.

Explanation of French terms:

Temps = time. — Sans préchauffage = without preheating. — Temperature intérieure (extérieure) = inside (outside) temperature. — Température de l'air soufflé = température of air blown in. — Température de l'eau, départ (retour) = water temperature before (after) circulation. — Début de l'essai = beginning of test.

On leaving the heaters, the air is distributed through the compartments in the same way as in the Renault railcar.

The floor is heated by circulating the engine cooling water through ribbed tubes at floor level.

In summer the air circulates in the same way as in winter, and passes over the heaters which are then fed with water from melted ice contained in special holders. The results obtained are given by fig. 49. The two installations

described above can be connected to the station mains in order to preheat the vehicles.

The triple railcars of the French Nord (1936 design).

The air conditioning equipment on the 1936 type triple sets is comparable to that adopted on the Renault railcar of the French State as regards distribution of hot air.

In winter, the outside air is filtered, passed over a heater fed by an independent coke-fired boiler, and then distributed through the 1st-class trailer through a longitudinal duct along the centre line of the ceiling.

In both end vehicles (2nd-class) the heating is by ribbed tubes, at floor level, along the sides.

The intermediate first-class trailer is provided with self-contained air-cooling equipment consisting of 2 Sicco-Glacia refrigerators using *Freon gas* (dichlorodifluoro-methane) as the cooling agent.

The air, after being cooled by passing it through these refrigerators, is distributed as previously through the centre duct.

The 2nd-class (end) coaches are simply ventilated.

The temperature is automatically regulated by the Moreau-Fèbvre device also used on the Renault and Bugatti railcars of the French State Rys.

* * *

CHAPTER VI.

Comparative tests.

Since the 1935 enlarged meeting of the Permanent Commission at Brussels, the French Railways carried on the various tests of railcars, and thanks to the methods resorted to, interesting comparisons of the various types have been made and on the other hand, existing designs have been improved.

Unfortunately the information sent in this respect by the different Administrations is very meagre and does not allow of useful comparisons being made between railcars of the various countries covered by this report.

(a) *Ferrand-Rousselet method.* — This method was described in the 1935 report and has been improved subsequently. It is now generally resorted to on the French Railways.

Thus, the characteristic constants of over twenty railcars have been ascertained ; a few of the results obtained are given hereafter. Whereas the running resistance constant of steel-tyred railcars varies between 1.4 kgr. and 2.6 kgr., that of pneumatic-tyred railcars is about 8 kgr.

The aerodynamic coefficient varies between 0.30 and 0.45 for single vehicles; it reaches 0.60 in the case of railcars hauling a trailer, when there is a gap between the two vehicles.

The overall efficiency of the transmission lies between 0.79 and 0.95 in the case of mechanical drives; in the case of gear ratios other than direct coupling to the engine, the overall efficiency varies between 0.77 and 0.95.

It is between 0.72 and 0.85 for electrical transmissions.

The same method has been used in order to improve existing railcars, by successive approximations.

For instance, the tests carried out have shown the importance of carefully selecting the type of silencer to be used; with an exhaust silencer of insufficient size, the overall mechanical efficiency of a railcar with direct drive (ratio of the power at the wheel tread to the power on the test bench of the engine with free exhaust) dropped quickly as the speed increased; the loss in the silencer then varied between 7 and 19 % ; with a muffler of larger dimen-

sions the mechanical efficiency with direct coupling became constant, the loss in the silencer being only 4 %.

Similar tests have shown the effect of the axle driving chains on the running resistance coefficient, the effect on the aerodynamic constant of the orienting of the railcar relatively to the running direction, in the case of a railcar with a raised driver's compartment located at the end of the vehicle.

(b) *Other tests.* — Among other interesting tests, may be mentioned those of the spring gear and the running qualities, provided for by the French Railways in order to study the effects of the track on the spring gear and stability of railcars, the comfort and operating safety of such vehicles depending on these characteristics.

These tests will include trial runs on each of the Railways concerned, and on the other hand, tests on a special track between Chartres and Gallardon; the test track, now being prepared, will include a double-track section with special features laid out purposely : superelevation, transition curve, etc., the different factors being made to vary.

On this section the vehicles to be tested will be run at increasing speeds following given timings, and they will carry all the necessary recording devices.

* * *

CHAPTER VII.

Maintenance methods.

Experience with the first railcars, the systematic investigations into the causes of failures, the work done by the builders, and laws followed in automobile maintenance practice, made it possible to lay down certain maintenance rules, which, though still not final, now form a fairly complete set.

The principles governing railcar maintenance are, after all, based on the classification of its parts into :

(*a*) relatively easily damaged parts, requiring very careful attention in service at all times;

(*b*) parts of average strength requiring periodical and frequent attention;

(*c*) parts of great strength, which can be left without inspection for long intervals,

and on the methodical and positive spreading over of the period for inspecting the parts or the details of parts defined above.

The various intervals between the examinations therefore depend upon the type of railcar, and consequently upon its components.

They all have, however, a common point; they are of a preventive nature.

As with all other rolling stock, steps ought to be taken to prevent failures rather than to record them.

Maintenance of this kind, rendered more difficult on most Railways by the diversity of the types in service and by the rapidity with which the railcar services have developed, requires a trained, specialized, young and well disciplined staff.

We insist upon the specialization of the men, because this is of the greatest importance, and it should be carried out in principle :

— by type of railcar ;

— and for each type by the kind of work to be carried out or the nature of the parts to be maintained.

In a well organised depot we should find :

— gangs for current maintenance work ;

— specialized gangs responsible for the periodical examinations.

These latter will include, in the case of a large depot, men specially trained to repair :

— engines;
— injection gear;
— gearboxes and reverse gears;
— electrical equipment;
— brake gear;
— safety devices.

Obviously, one man can deal with two or three of these sections when the type of railcar which he is maintaining only requires little work on each.

Railcar maintenance involves :

— daily maintenance ;

— periodical maintenance at rather close intervals fixed beforehand, of varying importance ;

— heavy repairs or complete overhaul of the engine and its accessories, transmission gear, running gear, and the body.

As a rule the engine, the bogies, and the body being parts quite independent from each other, the period between two repairs cannot be the same for each of them.

The engine should be overhauled after running 80 000 km. (50 000 miles) for example, whereas the bogies need only be repaired after 100 000 km. (62 000 miles) and the body after 200 000 km. (124 000 miles).

A. — **Daily maintenance.**

In principle this is carried out at the depot to which the railcar belongs, or, more rarely, by the depots at which the railcar calls.

In certain cases (fairly frequently in Italy) the railcar is away from its shed for a whole week to operate a separate service in some far-off district, from which it returns periodically for maintenance.

The daily maintenance is generally carried out by employees of the Railways, except on certain French Railways which have handed over this maintenance to contractors, as an experiment.

The depots at Bordeaux and Nancy are examples of places where this latter method has been adopted.

B. — **Periodical maintenance.**

This includes the inspection and maintenance of parts of average strength or size, and varies but little on the different Railways as regards the intervals between the operations. This maintenance is done either at the depots if the equipment is suitable, or in special shops, or contracted out, but only in certain particular cases in which the repairs to be carried out require special equipment or special knowledge.

On the Italian State Rys. the driver of the railcar helps with the periodical (weekly) inspection.

C. — **Heavy repairs.**

The Belgian National Railways Co. carries out in its own workshops all heavy repairs to railcar engines and bodies. Excellent results have been obtained since the engines have been repaired in the railway shops instead of being sent to the builders as previously. The time for repair has been reduced to 12 or 18 days according to the amount of work required.

The general overhauls of the Company's railcars are carried out in the Malines Central Workshops, as regards the bodies, bogies and equipment such as piping, reservoirs, control, etc. and by the Central Shops at Louvain as regards the engine.

For this purpose the following procedure is followed :

The depot to which the railcar belongs sends the railcar to the Central Workshop at Malines under its own power. This shop removes the engine and transmission and sends it to the shop at Louvain. Whilst the latter is carrying out the necessary repairs to the engine and mechanical transmission, the Malines Shop repairs the body, bogies, and equipment. The repaired engine is then returned

from Louvain to Malines where it is re-erected on the railcar.

When the railcar is equipped with an electric transmission, the latter is repaired at the Malines Shop.

The Louvain Shops are repairing 7 to 8 engines monthly, but the equipment, without extending or altering the shop, is capable of dealing with 15 to 20 engines.

In order to arrive at this result, the Belgian National Rys. Co. have reorganised part of the steam locomotive repair shops at Louvain and equipped them with up-to-date plant and tools.

The NETHERLANDS RYS. carry out heavy engine repairs and general overhauls of engines, transmissions and bodies in the Central Shops at Haarlem, which have been so equipped that this work is carried out in the most efficient way (figs. 50 and 51).

This shop has been arranged in two bays of a building consisting of eight ; each bay is 8 m. (26′ 3″) wide and about 100 m. (328′) long.

The equipment and the full and up-to-date machinery installed are sufficient for repairing 2 engines per week.

The ITALIAN STATE RYS. have also equipped, at Florence, a single Repair Centre which for the last year and a half has dealt with the general overhaul of motor bogies and special repairs of some importance (fig. 52).

The whole of the railcars in service on this railway have their engines mounted on the bogies, and the bodies are considered from the point of view of repairs as coaches and their general overhaul is dealt with in one of the carriage shops.

The installations at Florence are sufficient to deal with the heavy repairs of 400 motor bogies per annum.

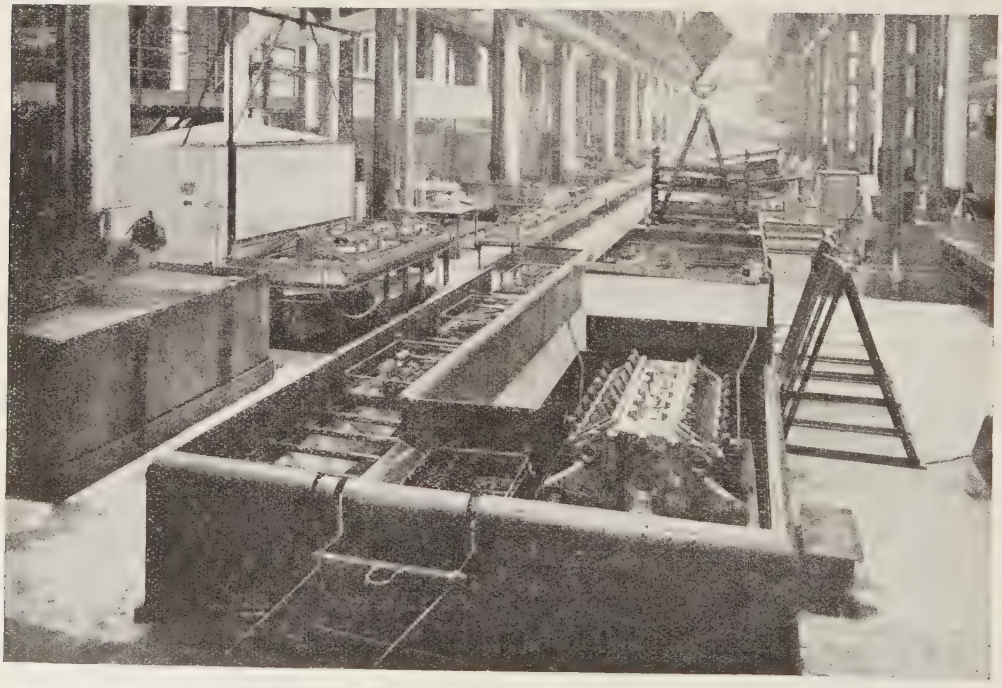


Fig. 50. — Cleaning tanks in the Harlem Workshops (Netherlands).

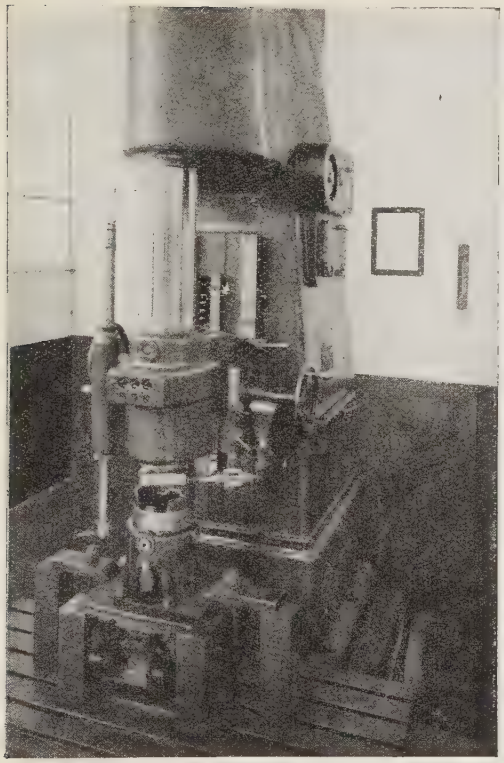


Fig. 51. — Vertical boring machine in the Haarlem Workshops (Netherlands).

These Shops are equipped with very complete and up-to-date machinery, installations such as hot water tanks for cleaning the bogies and details, and equipment for calibrating and testing compressors and pneumatic control devices, and for running in the engines, gear boxes, and axles.

This installation is completed by others for dealing with the auxiliaries such as the feed pumps, injectors, lighting, and starting gear.

The P.L.M. and State Rys. do part of the only ones to call upon the builder or private shops to carry out heavy repairs, or to replace standard parts : this latter method is an interesting one and consists in returning a worn part to the builder for a repaired part, as is the practice generally followed in road vehicles, and is justified by the relatively great number of types of railcars in service, and by the importance, when there are only a few railcars at a depot, of keeping down to a minimum the number of units out of service.

The Alsace-Lorraine Rys. send their Renault engines to the builder for repairs when their own shops are too busy.

The P.L.M. and State Rys. do part of the heavy railcar repairs in their own shops.

On the French State Rys. these heavy repairs are carried out in their shops at Rennes. The railcars are sent there after running 200 000 to 250 000 km. (125 000 to 155 000 miles) ; the engine is sent to the builder if need be for exchange ; the body accessories and bogies are repaired on the spot, the latter on the belt system.

Heavy repairs to the railcars are carried out in these shops, principally in winter, so that the whole of the stock is available during the summer when the shops repair the loco-tractors and trolleys.

The Est Railways carry out their general repairs in a Central Worshop as regards the body, but send the engines to outside firms.

On the French Nord Ry., heavy repairs to all railcars (bogies and bodies) of which there are a large number (T.A.R. Standard, Renault and A.B.J.) of the same designs in service, are carried out by private firms; but heavy repairs to railcars of types of which there are fewer in service are carried out in the workshops at Hellemmes.

On the P.O.-Midi Railways, heavy repairs are dealt with to a large extent by private workshops.

* * *

Period the vehicles are laid up for the various periodical repairs.

The period between repairs being more

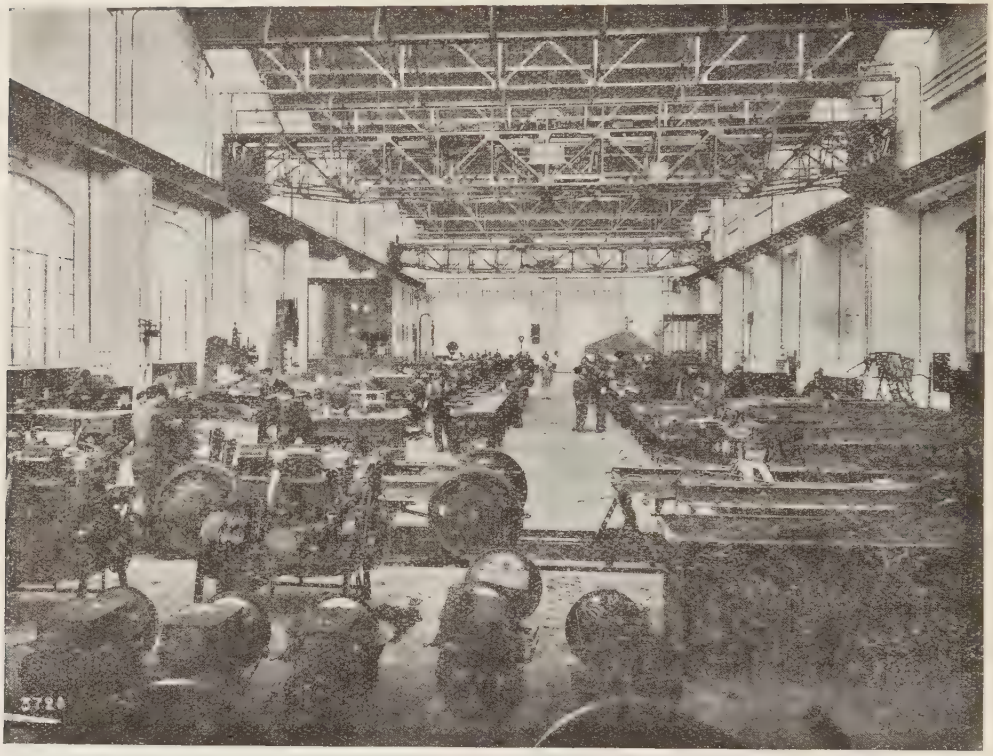


Fig. 52. — The railcar repair shops at Florence (Italy).

or less the same on all the French and foreign railways, the periods the vehicles are kept out of service are much alike.

On principle daily maintenance work does not require the car being taken out of service, as this lasts only 4 to 6 hours, and usually is done whilst the car is regularly stabled in the depot.

The first periodical light repair is usually carried out after running 4 000 to 5 000 km. (2 500 to 3 100 miles), and means stopping the vehicle a shorter or longer period according to whether the repair work is done during the day only or day and night.

Foreign Railways appear to follow the first method only, whereas the French Railways rather prefer the second.

On the French State Railways, in particular, the rule in most depots is that repairs are carried out during the night (fig. 53). Consequently very little immobilisation due to light repairs is reported. The average period for such repairs after 4 000 to 5 000 km. seems to be one day and exceptionally two days, when important and unexpected work has to be done. The first time the engine is decarbonised, usually between 20 000 and 40 000 km. (12 500 and 25 000 miles), the unit has to be stopped from 6 to 10 days according to the other work required. Finally on an average 4 to 7 weeks must be allowed when the vehicle is given a general overhaul.

To sum up, if all the periods are added together, it appears that the unit is stopp-

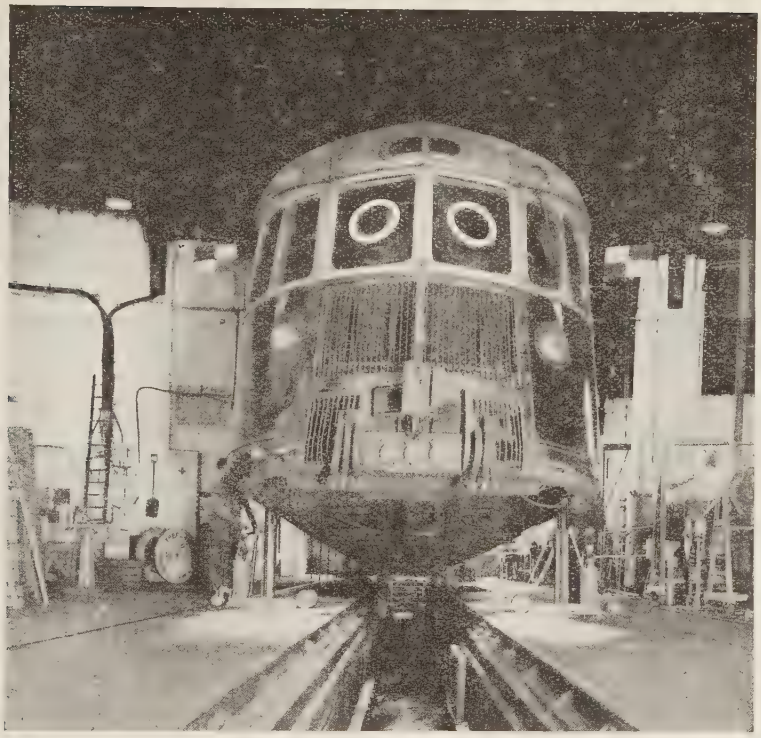


Fig. 53. — Lifting a Renault A.B.J. railcar by means of hydraulic Jacks (French State Rys.).

ed from 60 to 80 days for 120 000 km. (75 000 miles) run, if the maintenance work is done entirely by day.

If, on the other hand, the periodical light repairs (4 000 to 5 000 km. = 2 500 to 3 100 miles) are carried out entirely at night, the time the vehicle is standing is reduced to between 40 and 60 days.

The advice given by the makers, experience acquired with the stock in service, together with the teachings derived from damages to the equipment, allow of a « maintenance schedule » to be drawn up for each type of railcar, showing the various periodical inspections (it is important they should be adhered to exactly), for the different parts or components of well defined parts.

Below as an example is given a brief summary of the various examination periods adopted by the French Main-Line Railways for the whole of the rolling stock in service, with a brief list of the principal parts examined.

a) *Daily examination.*

This examination is carried out every 300 to 500 km. (136 to 310 miles) and consists of :

— the examination by the driver and a specialised shed employee of the different parts of the engine (valves, springs, joints, feed pumps, accessories, etc.) and of the railcar (water, fuel and brake pipes, electrical circuits, transmission and running gear, body, inside fittings);

— checking the oil levels in the different cases.

(b) *First periodical light repairs.*

This examination is usally carried out every 4 000 to 5 000 km. (2 500 to 3 100 miles), and relates more especially to :

— examining the different equipment on the oil and fuel oil circuits :

— checking the injectors and accessories in the case of diesel engines (gauging the injectors), and the feed in the case of petrol and gas engines ;

— checking the brake gear more thoroughly ;

— checking the electrical equipment.

(c) *Periodical decarbonising.*

According to the type of stock, the first decarbonising takes place after 20 000 to 40 000 km. (12 500 to 25 000 miles).

This operation consists of stripping down all such parts of the engine as the valves, springs, valve rockers, injectors, heads, manifolds, etc.

The cylinder block is sometimes lifted off so as to leave the pistons clear.

If need be the rods are taken down. After this :

— all the parts taken apart, especially the pistons and rings, are cleaned ;

— the crank case is cleaned out ;

— the valves and valve seats are ground in ;

— the play in the connecting rods is checked ;

— the valve gear and feed are checked over (the injection pumps of the diesel engines are sent to the test bench).

In some cases certain of these parts, such as the piston rings, pistons, cylinder liners and connecting rod pins and bearings have to be renewed on account of wear.

The present policy is a general overhaul of the engine, with the replacement of any worn parts by new parts of equal dimensions.

(d) *General overhaul.*

This operation takes place between 80 000 and 120 000 km. (50 000 to 75 000 miles).

It consists in systematically stripping all parts of the engine and also all the component parts.

Every detail is cleaned and examined separately in order to :

— detect cracks ;

— check the dimensions, so as to scrap any parts worn to the limit ;

— discover deformations or surface defects.

The search for cracks is carried out at the Louvain Shops (BELGIAN NAT. RYS. Co.) by first of all immersing the clean part in a bath of denatured alcohol with an admixture of finely divided chalk, and then drying them with a blow pipe burning town gas. The cracks appear as a black line on the white of the chalk.

The ITALIAN STATE RYS., in the Florence shop, use a magnetic apparatus with a liquid detector, which shows up cracks invisible to the naked eye, even below the surface.

In order to bring out surface defects the BELGIAN NAT. RYS. Co. uses a binocular lamp with a magnification of 35 diam. This is used to inspect the running surfaces of roller or ball bearings in order to reveal small holes almost invisible to the naked eye. Use is made also of a special lamp of intense luminosity to give an intense concentrated light on the parts to be inspected.

* * *

Bench tests.

Every general overhaul of the engine is necessarily completed by a more or less long test on a test bench in order to :

— run in the engine ;

— adjust certain parts of the valve gear ;

— check the water circulation ;

— check the power developed ;
— determine the efficiency of the engine from the point of view of fuel consumption ;
— and finally to see if there remain any minor defects.

As an example, the equipment installed in the Florence shops for the testing of engines before erection on the railcars is worth mentioning.

This equipment consists of 4 test stands for the engines alone and 2 for engines on their bogies.

The engine test benches are provided with :

(*a*) a Froude hydraulic brake for powers up to 1 000 h.p.;
(*b*) an engine cooling water cooling plant;
(*c*) an oil cooling plant;
(*d*) a blower for improving the cooling of the engine crank cases;
(*e*) devices for controlling the temperature of the oil and water, as well as the circulation of water, with special pilot lamps;
(*f*) electric plant for starting and ignition purposes;
(*g*) exhaust gas pipe with cooling device.

It is important to note that when the engines are run in on a test bench, the period required to work them in in service is reduced considerably.

Unlike the steam locomotives, the period during which the stock is used with reduced loads after heavy repairs is very short. After an average of 300 to 400 km. (186 to 250 miles) each railcar after heavy repairs can work a full service as though it were new stock. It should be noted that the time for taking down and re-erecting the engines during these different periodical repairs are relatively short if compared with the total time taken for repairs and especially with that for similar repairs to a steam locomotive.

It is to be hoped, therefore, that when the railcar is thoroughly perfected and the maintenance procedure clearly defined, an appreciable amount of time will be saved on its repairs as a whole, which will reduce proportionally the amount of time the rolling stock is out of commission. This would be a great advantage over steam services.

Plant and tools required for maintenance.

Daily and periodical maintenance of railcars obviously requires special equipment for the different maintenance tasks, according to the nature of the parts concerned.

The Railways generally speaking have made a great effort to equip the railcar depots with up to date plant suited to the repairs to be done.

The equipment at a railcar maintenance centre can be divided into 3 groups :

1. Equipment for daily maintenance;
2. Equipment for light and heavy periodical repairs;
3. Special equipment for testing the various apparatus.

1. *Equipment for daily maintenance* can be subdivided in turn into :

(a) Plant for dealing with the distribution of liquid fuels.

The depots are generally supplied with fuel in tank wagons. This fuel is purified very thorougly by centrifugal filters, which eliminate all impurities which it may still contain.

The railcar fuel tanks are filled by means of mobile containers designed to suit different types of vehicles.

In certain centres the stocks and pumps have been installed at the entry to the sheds. In these cases the reservoirs are filled from meter-pumps similar to those used by automobiles.

It should be noted that the use of mobile containers or pumps requires special fittings on the railcar tanks.

The tanks can be filled without any

fear of spilling the fuel, which considerably reduces the fire risks, and the filling is stopped automatically when the tanks are full.

(b) *Equipment for current repairs.*

The various tools required by the driver and fitters to do the work as easily and as quickly as possible for each type of car have to be decided.

It includes all the tools ordinarily used by fitters and the special tools required in connection with the components of the railcars.

2. *Equipment for periodical medium and heavy repairs includes :*

— the whole series of special tools for erecting the engine, according to the type of engine or railcar maintained at the depot or shop concerned, specially designed to reduce to a minimum the time required for stripping and re-erecting the various parts ;

— the necessary equipment for methodically dismantling assembled units or parts thereof.

This equipment is sub-divided into plant for :

(*a*) Lifting or handling plant	fixed or travelling gantry cranes, jacks, trolleys.
(*b*) Carrying the parts taken down (jigs, etc.)	special supports for engine frames, crank shafts, cylinder heads, etc.
(*c*) Cleaning the parts	washing tanks, high-pressure pump.
(*d*) Sorting the parts	re-erecting benches, appropriated racks and shelves.
(*e*) Repairing the parts	work benches, vices.
(*f*) Truing	truing machines (valves, valve seats).
(*g*) Checking	comparators, gauges, micrometers, calipers.

3. *Special equipment for testing the apparatus.*

As an example we may quote the special plant required for inspecting the injectors of diesel engines, and accessories.

Actually, after a certain mileage has been run, it is not possible to set the injectors to the desired pressure and leakage may occur ; in addition the injection pumps can get out of order and inject into each cylinder different quantities of oil. These defects result in the cylinders being stressed differently, and consequently great care must be taken to prevent them, in order to avoid certain mishaps such as the anti-friction metal coming away from the connecting rod bearings, which can be eliminated in this way.

These various operations require very special plant which some of the French Railways have installed in their more important diesel railcar depots. In Italy such tests are centralised at Florence in the single repair shop.

A test laboratory of such a kind should include :

— a test bench for setting the injectors ;

— a test bench for measuring the quantities of oil supplied by the injection pumps (fig. 54).

— and finally a test bench for checking the injection points and the adjustment between two or several pumps of the same group.

These laboratories should be completed by the necessary plant for the complete repair of groups of pumps (benches, for stripping and examination; individual work benches, tanks for cleaning

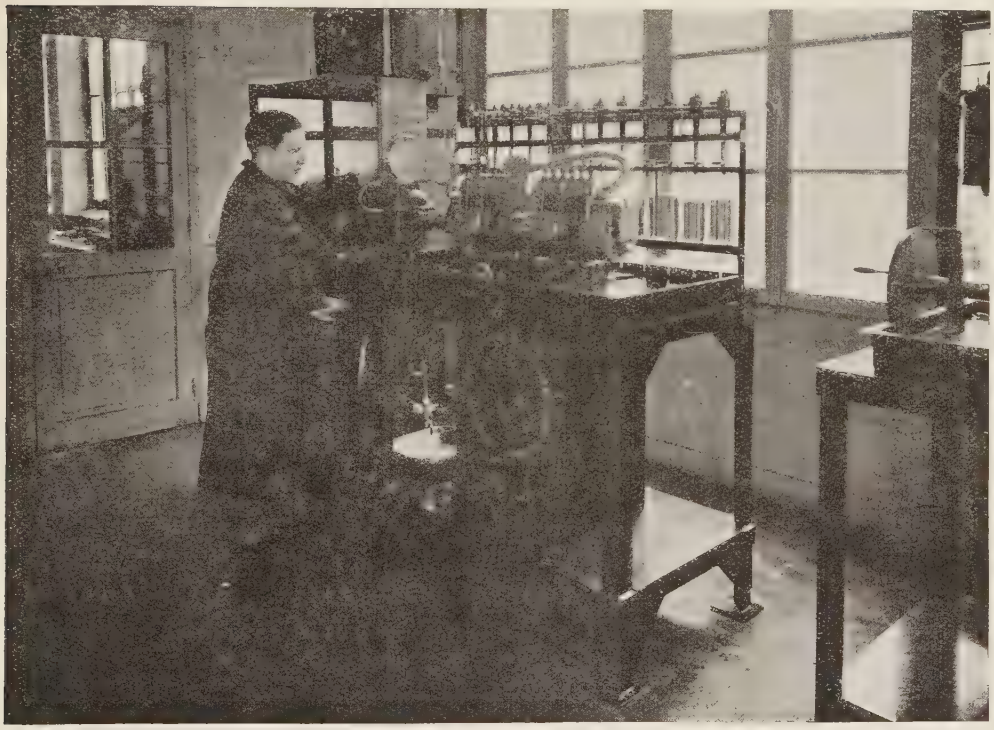


Fig. 54. — Testing injection pumps — measuring the delivery (French State Rys.).

the details, appropriated racks, and a set of special tools).

Laboratories, such as those in which precision work is done should be reserved entirely for maintaining the injection gear.

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CHAPTER VIII.

Cost price.

It is rather difficult to compare the cost of the railcar-kilometre on the different Railways. On the one hand, the costs of labour, fuel and materials are not the same ; on the other hand, the expenditure has to carry general charges which may or may not include the management costs of the railcar depots, or even part of the headquarters management costs.

In order to obtain a comparison of costs based on comparable accounting methods, we asked the Administrations to give us, with the cost price of their railcars, the cost price of their light steam-hauled trains.

We only received a few replies.

The Belgian National Railways Company and the French Main Line Railways fortunately sent very complete information on those of their railcars which have the greatest mileage to their credit ; this information has enabled us to make some interesting remarks, for which we wish to thank these Administrations.

A. — **Total and annual distances run by modern railcars.**

The investigation into the annual distances covered by railcars should logically preceed any consideration of the cost price as the distance run plays a double part in the expenditure on a railcar. Only after a sufficient mileage, say above 62 000 (100 000 km.) do the general repairs of the body come into the cost. In addition the greater the annual mileage, the lower the capital charges per

TABLE I.

Classes of modern railcars which had covered the longest distance at the 31 October 1936.

CLASS.	Year put into service.	Average total distance per railcar at 31-10-36.	Total distance for the class at 31-10-36.	Remarks.
BELGIUM.				
BELGIAN NAT. RYS. CO.				
3 *Sentinel.* . . . . . 100 H.P.	1931	574 688	1 724 064	Steam.
3 *Eva-Maybach* . . . . . 175 H.P.	1931	537 189	1 611 567	
14 *Brugeoise-Maybach.* . . 175 H.P.	1933	302 619	4 236 666	
5 *Ganz.* . . . . . 175 H.P.	1934	155 503	777 515	4-wheeled.
FRANCE.				
ALSACE-LORRAINE.				
10 *Renault* . . . . . 220 H.P.	1934	166 603	1 666 030	
11 *De Dietrich* . . . . . 210 H.P.	1934	159 989	1 759 879	
EST.				
2 *Michelines* — 36 seats.	1933	254 642	509 284	Pneum. tyres.
2 *Michelines* — 56 seats.	1934	183 900	367 800	Do.
2 *Charentaises* . . . . . 115 H.P.	1934	169 130	338 260	
6 *Renault V.H.* . . . . . 220 H.P.	1933	253 980	1 523 880	
STATE.				
10 *Renault T.E.*	1930	261 784	2 617 840	4-wheeled.
6 *Renault Z.O.*	1934	250 055	1 500 330	4-wheeled.
43 *Renault V.H.* 220 and 265 H.P.	1933	216 910	9 327 130	
18 *Michelines* — 36 seats.	1934	152 277	2 780 986	Pneum. tyres.
6 *Bugatti* . . . . . 800 H.P.	1933-34	160 696	964 176	
4 *Charentaises* . . . . . 90 H.P.	1933	167 757	671 028	
NORD.				
4 *Michelines* — 24 seats.	1932-33	306 511	1 226 044	Pneum. tyres.
6 *Michelines* — 36 seats.	1934	258 370	1 550 220	Do.
2 *Michelines* — 56 seats.	1935	175 946	351 892	Do.
2 *Franco-Belge* — 1934 type, 810 H.P.	1934	268 118	536 236	Triplet.
P.L.M.				
6 *Charentaises* . . . . . 80 H.P.	1933	222 045	1 332 270	
3 *Bugatti* . . . . . 800 H.P.	1934	194 939	584 817	Coupled.
15 *Renault V.H.* 220 and 265 H.P.	1934	168 570	2 528 550	
2 *Aciéries du Nord* . . . 170 H.P.	1933	164 355	328 710	
P.O.-MIDI.				
8 *Charentaises* . . . . . 90 H.P.	1933-34	229 196	1 833 568	

kilometre run, if, as on most Railways, we admit that the cost of the amortization of the railcar should be spread over a certain number of years.

We give therefore two tables to begin with :

Table I shows the modern railcars with the highest average mileage ;

Table II gives the modern railcars with the highest average distance run during the last twelve months for which statistics are available.

TABLE II.

Classes of modern railcars which covered the longest distances in 1936.

CLASS.	Average distance covered per railcar. Period of one year.	REMARKS.
BELGIUM.		
BELGIAN NATIONAL RYS. CO.		
14 *Brugeoise-Maybach*, 175 H.P.	94 940	
3 *Sentinel*, 100 H.P.	69 130	
5 *Ganz*	63 150	
FRANCE.		
ALSACE-LORRAINE.		
10 *Renault* V.H., 220 H.P.	82 440	1st. Jan. 1936 to 1st. Jan 1937.
11 *De Dietrich*, 210 H.P.	86 783	1st. Jan. 1936 to 1st. Jan 1937.
EST.		
8 *De Dietrich*, 210 H.P.	86 568	1st. Jan. 1936 to 1st. Jan 1937.
6 *Renault* A.B.J., 265 H.P.	103 668	1st. Jan. 1936 to 1st. Jan 1937.
6 *De Dietrich*, 320 H.P.	81 892	15th May 1936 to 1st Dec. 1936, i.e. 7 1/2 months.
STATE.		
42 *Renault*, V.H.	104 934	
17 *Michelines*. 56-seater	70 984	
6 *Renault* 80, 4-wheeled	104 588	1st. Jan. 1936 to 1st. Jan 1937.
8 *Bugatti*, 800 H.P.	65 400	1st. Jan. 1936 to 1st. Jan 1937.
12 *Bugatti*, 400 H.P.	62 814	1st. Jan. 1936 to 1st. Jan 1937.
6 *De Dietrich*, 210 H.P.	91 043	1st. Jan. 1936 to 1st. Jan 1937.
NORD.		
4 *Michelines*, 24-seater	88 640	
6 *Michelines*, 36-seater	111 680	1st Febr. 1936 to 1st Febr. 1937.
2 *Michelines*, 56-seater	129 770	1st Febr. 1936 to 1st Febr. 1937.
10 *Renault*	106 140	
2 *Franco-Belge*, 820 H.P. — 1934 type.	132 000	1st Nov. 1935 to 1st Nov. 1936.
P.L.M.		
4 *Charentaises*. 80 H.P.	91 700	1st Jan. 1935 to 1st Jan. 1936.
4 *Renault* double, A.B.V., 530 H.P.	98 850	1st March 1936 to 1st March 1937.
3 *Bugatti* double, 800 H.P.	102 525	1st March 1936 to 1st March 1937.
P.O.-MIDI.		
2 *Michelines*, 56-seater	93 940	1st. Jan. 1936 to 1st. Jan 1937.
15 *Renault* V.H., 220 H.P.	81 751	1st. Jan. 1936 to 1st. Jan 1937.
12 *Renault* A.B.J.. 265 H.P.	101 266	Febr.-May 1936 (period in which put into service) to 1st Febr. 1937.

Table I shows that, at the 31st October 1936, four large classes of Belgian railcars of various makes, had covered GEOISE-MAYBACH and GANZ) had covered on the average over 150 000 km. (93 000 miles), six railcars of the first class having covered over 500 000 km. (310 000 miles) each.

At the same date, in France, nine large classes of railcars, made up of about 170 railcars of various makes, had covered over 150 000 km. on the average, a large number have covered more than 250 000 km. (155 000 miles) individually.

Table II shows that the good classes of railcars for secondary (branch) lines, currently run more than 90 000 km. (56 000 miles) per vehicle and per year ; the good classes for very fast services normally reach 120 000 km. (75 000 miles) and over. Such mileages are larger than those of the corresponding fast steam trains.

B. — Cost of the railcar-kilometre. Comparison with the light steam-operated train.

As it would be impossible to give the average cost of the whole of the railcars of a given Railway, we have selected certain typical classes of railcars of which we give the detailed costs with a few comments.

1. *Cost per kilometre of 14 La Brugeoise-Maybach 175-*H.P. *railcars* for the first half of 1936. (Total distance run : 685 709 km. = 421 120 miles).

	Francs.
Staff (driver only)	0.45
Fuel	0.25
Lubricants	0.08
Heating	0.01
General charges (road service)	0.14
Preparatory work	0.12 incl. 0.02 for materials.
Current maintenance	0.43 incl. 0.14 for materials.
Repairs and periodical overhaul in Central Workshops	
(*a*) Engine	0.32 incl. 0.19 for materials.
(*b*) Gearbox	0.05 incl. 0.03 for materials.
(*c*) Carriage	0.26 incl. 0.09 for materials.
Amortization	0.52
	2.56 incl. 0.47 for materials.

The cost per kilometre of a light steam train in Belgium is 4.16 fr., so that the cost per kilometre of a bogie railcar with 104 seats is only 61 % of that of the light steam-operated trains.

2. *The cost, per kilometre run, of various French railcars,* is shown in the table on the following page.

The cost per kilometre of the light steam train was 7.136 fr. on the French Est Rly, so that the cost of a 75-seater bogie railcar comes to 60 % of that of the light steam-operated train.

This 60 % proportion is confirmed with very different types of railcars to those considered above, such as the FRANCO-BELGE 1934 triplets of the NORD, the kilometric cost of which is compared with that of an express steam train of the same railways in an article recently published in the Journal *Traction Nouvelle.*

	16 Michelines. 56 seats. STATE.	8 de Dietrich. 210 H.P. EST.
Driving staff (general charges 31 %) . . .	0.343	0.253
Fuel and lubricants (General charges 10 %).	1.034	0.608
Engine and running gear repairs :		
Labour { Shed (general charges 56 %) .	0.298	0.496
Labour { Shops (general charges 106 %) .	0.005	0.100
Materials, and repairs to engines by contract (general charges 10 %)	0.475	0.710
Body maintenance :		
Labour { Shed (general charges 56 %) .	0.010	0.252
Labour { Shops (general charges 106 %) .	0.030	0.109
Materials (general charges 10 %)	0.045	0.048
Cleaning :		
Labour (Shed, general charges 56 %). . .	0.175	0.066
Materials (general charges 10 %)	0.026	0.001
Charges to be paid to builders (pneumatic tyres)	0.521	...
Amortization	1.00 (in 7 years)	1.40 (in 6 years)
Guard	0.23	0.26
	4.20 fr.	4.30 fr.

The total expenditure per kilometre covered by a triple unit, based on 520 000 km. (323 000 miles) is as follows.

Driver and guard	0.53 fr.
Fuel oil	0.96 fr.
Lubrication and miscellaneous . .	0.54 fr.
Body :	
Repairs	0.42 fr.
Daily cleaning	0.31 fr.
Engines, bogies, brake, electrical equipment	3.94 fr.
Shed costs and social charges . . .	0.40 fr.
Interest and amortization	2.90 fr.
	10.00 fr.

The cost per kilometre of the express train on the French Nord is 18 francs.

C. — Annual cost price of railcars of a given class.

Unlike what might have been expected, the cost per kilometre does not increase appreciably as the railcar gets older. Doubtless this is due to the fact that the various details of the rail motor car, particularly of the engine, are renewed during repairs to the as new condition, so that, provided the frame remains in good order, the railcar is always in a more or less constant state of repair.

This very important conclusion is proved by comparing the annual costs per railcar-kilometre for four types which have run considerable distances, detailed information about which has been supplied by the Railways, to wit :

(A) Belgian National Rys. Co. — 3 *Sentinel* 100-H.P. steam railcars put into service in 1931, having run at the end of 1935 a total of 1 564 612 km. (972 222 miles) or 521 537 km. (324 074 miles) on the average per railcar.

BELGIAN NATIONAL RAILWAYS COMPANY.

Annual cost price per kilometre run (in Belgian francs).

	(A) 3 *Sentinel*, 100 H.P.					B) 14 *Brugeoise-Maybach* 175 H.P.				Light train.
	1931	1932	1933	1934	1935	1933	1934	1935	1st half. 1936	1935
Driving staff.	1.24	1.02	0.92	0.89	0.91	0.44	0.44	0.41	0.45	0.97
Fuel and lubricants . . .	0.62	0.62	0.56	0.54	0.59	0.32	0.30	0.27	0.27	1.32
General road service charges	0.48	0.40	0.28	0.15	0.15	0.09	0.08	0.11	0.14	0.26
Repairs to stock	0.18	0.10	0.12	0.16	0.17	0.10	0.10	0.12	0.12	0.11
Current maintenance (shed)	0.21	0.44	0.28	0.45	0.60	0.43	0.43	0.42	0.43	0.37
Repairs and periodical repairs at the Central Shops.	0.00	0.00	0.21	0.00	0.08	0.00	0.32	0.54	0.63	0.68
Passenger carriages (light steam train)	»	»	»	»	»	»	»	»	» .	0.45
Amortization	0.82	0.82	0.82	0.82	0.82	0.52	0.52	0.52	0.52	0.00
Total. . . .	3.55	3.40	3.19	3.01	3.32	1.90	2.19	2.39	2.55	4.16

FRENCH RAILWAYS.

Annual cost price per kilometre run (in French francs).

—	(C) 10 *Renault*, 4-wheeled, 80 H.P.				(D) 6 *Renault*, 220 H.P.			Light train.
	1933	1934	1935	1st half. 1936	1934	1935	1st half. 1936	1935
Driving staff.	0.328	0.284	0.331	0.347	0.319	0.321	0.299	3.564
Fuel and lubricants	0.370	0.367	0.381	0.377	0.738	0.646	0.641	
Maintenance of engine and running gear	0.458	0.576	0.784	0.449	0.688	1.421	1.276	2.072
Maintenance of body and cleaning	0.053	0.268	0.416	0.520	0.318	0.609	0.551	...
Passenger carriages (light train)	...	...	...	...	...	...	...	1.500
Amortization	0.65	0.65	0.65	0.65	1.10	1.10	1.10	...
Total	1.859	2.145	2.562	2.343	3.163	4.095	3.867	7.136

(B) Belgian National Rys. Co. — 14 *La Brugeoise* bogie railcars with 175 h.p. Maybach engines, put into service in 1933, having run to by the end of the first half of 1936 a total of 3 916 957 km. (2 433 932 miles), i.e. 279 068 km. (173 408 miles) on the average per railcar.

(C) French State Rys. — 10 four wheeled *Renault* 80-h.p. railcars put into service in 1933, which at the end of the first half of 1936 had run a total of 2 244 000 km. (1 394 380 miles), or 224 400 km. (139 438 miles) on the average per railcar.

(D) French Est Rys. — 6 *Renault* 220-h.p. bogie railcars put into service at the end of 1933, having run at the end of the first half of 1936, a total of 1 426 842 km. (886 612 miles), or 237 807 km. (147 777 miles) per railcar.

The two tables on p. 1438/196, one for the Belgian National Rys. Co. and the other for two French Railways, give the detailed cost price per kilometre, year by year, of these railcars, and that of a light steam train in the last column.

So that the comparaison should be quite correct, an addition is made to the cost of the rail motor cars for amortization, but nothing has been added to the cost price per kilometre of the light steam train, seeing that these trains are operated by old rolling stock which has been written off.

As already stated, the annual cost per railcar kilometre does not increase appreciably as the railcar gets older.

With certain types of railcar, this cost is almost constant.

The slight increase shown in the other cases is undoubtedly due to the cost of heavy repairs to the body, which appear in the accounts only after several years' service.

In addition, the cost per railcar-kilometre is more or less equal in the case of well designed bogie stock to 60 % of that of a light steam train.

The steam train retains the advantage of much greater capacity, but as very often this capacity does not correspond to the traffic requirements from end to end of the line, the railcar in many cases provides the more economical working, even though it has to make several runs over that section of the line on which the passenger traffic is the heaviest.

APPENDIX I.

Railcars in the different countries

GREAT BRITAIN and IRELAND.

The British Railways first entered the railcar field and if one considers the development of railcars in Great Britain, three clearly marked stages will be noticed: first stage, 1903, when the Great Western introduced the steam railcars; 2nd stage, 1935, the *Sentinel* Works having perfected the first up-to-date steam railcar, the Railways ordered a number from the firm; 3rd stage, 1935, the Railways appear to turn towards diesel railcars and the motor train.

At the present time there are 36 diesel railcars and 2 diesel trains in service in the British Isles.

London & North Eastern Railway (L.N.E.R.).

This railway owns over 100 railcars, only 4 of which have diesel engines and were built by ARMSTRONG-WHITWORTH. All the others are steam railcars, ten CLAYTON and over 80 SENTINEL.

The L.N.E.R. considers that a railcar should have sufficient power to haul one passenger trailer on busy days, and be able to work to the same timetable on that day.

London, Midland & Scottish Railway (L.M.S.R.).

The L.M.S.R. at the present time owns 15 SENTINEL steam railcars, and 3 LEYLAND 130-H.P. diesel railcars.

This Railway, at the present time, has under construction at the Derby Works 1 triple unit diesel train with Leyland engines and hydraulic transmission.

Leyland 4-wheeled railcars with one 90-H.P. engine (three units in service).

The original Leyland 130-H.P. engine (2 200 r.p.m.) has been replaced by a 90-H.P. engine; the engine is carried by the frame under the floor, in the centre of the vehicle, so that it does not take up any floor space inside the vehicle.

LYSHOLM-SMITH hydro-mechanical transmission; a 2-position lever engages the driving shaft, either with the main shaft of the transmission, or directly with the secondary shaft (direct drive); the secondary of the hydraulic transmission drives the driven shaft through a free wheel, so that on direct drive the hydraulic transmission is cut out, the pump and turbine being completely stopped.

Great Western Railway (G. W. R.).

With the collaboration of the ASSOCIATED EQUIPMENT COMPANY, of Middlesex, this Railway designed in 1934 an interesting diesel railcar known as the A.E.C. — 18 of these A.E.C. are in service, one fitted with a single 130-H.P. and the others with two 130-H.P. A.E.C. engines. Railcar No. 17 is specially fitted out for dealing with luggage, and parcels. No. 18 is designed to haul one or several trailers; the whole unit (motor car + trailer) are reversible, i.e. can be driven in both directions).

Four-wheeled, A.E.C. railcars, with two 130-H.P. engines (18 units in service).

The two 130-H.P. 6-cylinder Ricardo engines are mounted on the side of the unit on an independent frame suspended from the main frame through rubber blocks; they are carried longitudinally under the floor outside the sole bars and do not project inside the vehicle.

They are fitted with pre-selective Wilson gearboxes giving 5 speeds.

Maximum speed 120 km. (75 miles) an hour.

County Donegal Railway (Ireland).

The County Donegal Ry. was the pioneer of diesel traction in Ireland by putting into service in 1931 two railcars with Gardner 74-H.P. diesel engines, and since this period three other similar units have been put into service.

Great Southern Railways (Ireland).

This Railway has three DRUMM accumulator railcars in service.

Northern Counties Committee (Ireland) (L.M.S.R.).

The Northern Counties Committee, after having used a 2-engined petrol railcar for local services over a period of 18 months, put into service, in 1934, a bogie railcar with two 130-h.p. Leyland diesel engines capable of hauling 2 trailers.

Experience has shown the value of this design, and in June 1936 the Railway put into service a further railcar also with two 130-h.p. Leyland diesel engines.

Leyland railcars with two 130-h.p. diesel engines (two units in service).

Two 130-h.p. Leyland diesel engines.

Leyland torque converters.

The engines and transmission are carried on a special frame underneath the floor in the middle of the vehicles.

80 seats.

Maximum speed: 113 km. (70 miles) an hour.

There is a raised driver's compartment at each end of the vehicle.

Great Northern Railway (Ireland).

In view of the satisfactory results obtained on the County Donegal Ry., the Great Northern put into service, in 1932, two diesel railcars with 120 and 130-h.p. engines.

In 1934, a 96-h.p. railcar was put into service, and was soon followed by two similar vehicles which could be coupled together.

This Railway has just put into service two articulated triple-unit diesel trains with one 150-h.p. engine (fig. 55); in addition it has

Fig. 55. — Railcar with 150-h.p. Gardner engine, Great Northern Railway, Ireland.

under construction an articulated rake with two 130-H.P. Leyland engines.

Articulated diesel trains with 150-H.P engines (2 units in service).

One Gardner diesel engine developing 150 H.P. at 1 200 r.p.m. in the middle unit.

Wilson epicyclic pre-selective gear box. Vulcan-Sinclair hydraulic transmission.

159 seats.

Weight : 39.5 tons.

Maximum speed : 68 km. (42 miles) an hour.

GREAT-BRITAIN AND IRELAND.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. *(miles)*.	Number of wheels.	Weight empty, in working order, metr. t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*.	Kind of service.
In service.									
L.N.E.R.									
About 100 steam railcars of various types, 80 to 200-H.P. *3 Armstrong railcars with one 250-H.P. Armstrong-Sulzer engine.*									
Elec.	Armstrong-Withworth.	100 *(62)*	8	42.5 *(41.8)*	Rev. Trailer.	60	1932/1934	180 000 *(111 850)*	Express and local.
1 Armstrong railbus with one 95-H.P. Armstrong-Saurer engine.									
Elec.	Armstrong-Withworth.	90 *(56)*	8	19 *(18.7)*	Rev.	57	1934	115 000 *(71 500)*	Local.
L.M.S.R.									
15 Sentinel steam railcars. *3 Leyland railcars with one 90-H.P. Leyland diesel engine.*									
Hydr.	Lysholm-Smith.	100 *(62)*	4	10.5 *(10.3)*	Rev.	40	1933	...	Local.
G.W.R.									
1 A.E.C. railcar with one 130-H.P. A.E.C. diesel engine.									
Mech.	Wilson.	120 *(75)*	8	30 *(29.5)*	Rev.	44	1934	...	...
15 A.E.C. railcars with two 130-H.P. A.E.C. diesel engines.									
Mech.	Wilson.	120 *(75)*	8	30 *(29.5)*	Rev.	...	1934/35/36	...	...
1 A.E.C. railcar with two 130-H.P. A.E.C. diesel engines (luggage).									
Mech.	Wilson.	120 *(75)*	8	30 *(29.5)*	Rev.	...	1936	...	...
1 A.E.C. railcar with two 130-H.P. A.E.C. diesel engines.									
Mech.	Wilson.	120 *(75)*	8	30 *(29.5)*	Rev. Trailer.	...	1936	...	...

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. *(miles)*.	Number of wheels.	Weight empty, in working order, metr. t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*.	Kind of service.
COUNTY DONEGAL RAILWAY (Ireland).									
5 railcars with two 74-H.P. diesel engines.									
NORTHERN COUNTIES COMMITTEE (Ireland).									
1 Leyland railcar with two 130-H.P. Leyland petrol engines.									
Hydr.	Leyland.	105 *(65)*	8	30 *(29.5)*	Rev. Trailer.	62	1933	Yearly 105 000 *(65 400)*	Local.
1 Leyland railcar with two 130-H.P. Leyland diesel engines.									
Hydr.	Leyland.	97 *(60)*	8	21 *(20.7)*	Rev. Trailer.	84	1934	Yearly 105 000 *(65 400)*	Local.
1 Leyland railcar with two 130-H.P. Leyland diesel engines.									
Hydr.	Leyland.	116 *(71)*	8	25 *(24.6)*	Rev. Trailer.	80	1936	...	Local.
GREAT NORTHERN (Ireland).									
5 railcars of various designs with one 100-H.P. (approx.) engine. *2 Diesel trains with one 150-H.P. Gardner diesel engine.*									
Mech. Hydr.	Wilson. Sinclair.	68 *(42)*	14	40 *(39.3)*	Rev.	159	1936	...	...
Under construction.									
L.M.S.R.									
2 diesel triplets with four or six 130-H.P. Leyland engines.									
Hydr.	Leyland.	113 *(70)*	16	75 *(74)*	Rev.	164	...	...	...
GREAT NORTHERN (Ireland).									
1 diesel triplet with two 130-H.P. Leyland engines.									
Hydr. Mech.	...	...	...	...	...	...	...	...	...

INDIA, DOMINIONS and COLONIES.

New Zealand.

The New Zealand Government Railways have put into service their first Leyland railcars; these six-wheeled vehicles are fitted with a 130-H.P. Leyland engine with hydraulic torque converter (fig. 56).

They operate between Wellington, Masterton and Palmerston North (214 km. = 133 miles) over the Rimataka gradient, 1 in 14 for 4.8 km. (3 miles).

India.

The *Madras & Southern Mahratta Railway* has had six rail motor cars in service since 1935; these cars are fitted with Armstrong-

Fig. 56. — LEYLAND railcar, New Zealand Government Rys.

Fig. 57. — 64-H.P. railcar, South Indian Ry.

Saurer 135-h.p. diesel engines, and seat 110 passengers.

The *South Indian Railway* has had three bogie railcars in service since 1915, which are now fitted with either 64 or 44-h.p. Gardner diesel engines (fig. 57).

The *Bombay, Baroda & Central India Railway* has three Sentinel double steam railcars seating 116.

BELGIUM.

The **Belgian National Railways Company** has in service at the present time 43 railcars of the following types :

5 with steam engines;

27 with diesel engines and mechanical transmission;

11 with diesel engines and electric transmission.

In addition, a railcar with a steam turbine and electric transmission is being designed.

All these railcars are reversible and have two driver's compartments.

The *Belgian National Rys. Co.* also intends to place an order for two types of railcar, one for stopping (local) services, and the other for fast through services.

The railcar for stopping services is a bogie vehicle with a central vestibule, with 70 seats; the diesel engine will be of 300 to 350 h.p., and the maximum speed 100 km. (62 miles) an hour.

The railcar for fast through services is a triple-unit articulated set carried on 4 bogies and will be equipped with two 400-h.p. engines; the drive will be hydraulic or electric.

The maximum speed will be 150 km. (93 miles) an hour.

« *Nivelles-Sentinel* » *bogie railcar with two steam engines 125-h.p. each (1 unit in service).*

The engine is a 2-cylinder compound developing, 125 h.p. at 1 500 r.p.m.; Stephenson link motion valve gear and piston valves are used.

The Sentinel Woolnough horizontal boiler is placed in a driver's compartment.

The coal consumption is about 7.5 kgr. per km. (26.6 lb. per mile).

The engine is carried on the driving bogie.

71 seats.

Maximum speed : 90 km. (56 miles) an hour.

Weight empty : 41 t. (40.35 Engl. tons).

« *Braine-le-Comte S.E.M.* » *bogie railcar with one 220-h.p. Carels-Ganz diesel engine* (1 unit in service).

Carels-Ganz diesel engine 220-h.p., at 1 330 r.p.m., 6 cylinders in line.

Carels-Ganz mechanical transmission 100 seats.

Weight empty : 30 t. (29.5 Engl. tons).

Maximum speed : 82 km. (60 miles) an hour.

« *Baume-Marpent S.E.M.* » *bogie railcar, with one Carels-Ganz 320-h.p. diesel engine* (1 unit in service).

Carels-Ganz diesel engine developing 320 h.p. at 1 330 r.p.m., with 8 cylinders in line.

Mechanical transmission with the S.L.M. Winterthur gearbox controlled automatically by Carels electro-valves.

70 seats.

Weight empty : 38 t. (37.4 Engl. tons).

Maximum speed : 85 km. (52.8 miles) an hour.

« *Forges, Usines et Fonderies Haine-St.-Pierre* » *bogie railcar with 1 Mercedes-Benz 330-h.p. diesel engine* (1 unit in service).

One Mercedes-Benz diesel V-type engine developing 330 h.p. at 1 700 r.p.m.; 12 cylinders.

Mechanical transmission by S.L.M. Winterthur gearbox.

70 seats.

Weight empty : 36 t. (35.4 Engl. tons).

Maximum speed 90 km. (56 miles) an hour.

« *La Brugeoise* » *and* « *Baume-Marpent* » *triplets carried on 4 bogies, with 2 diesel engines, with automatic A.C.E.C. and*

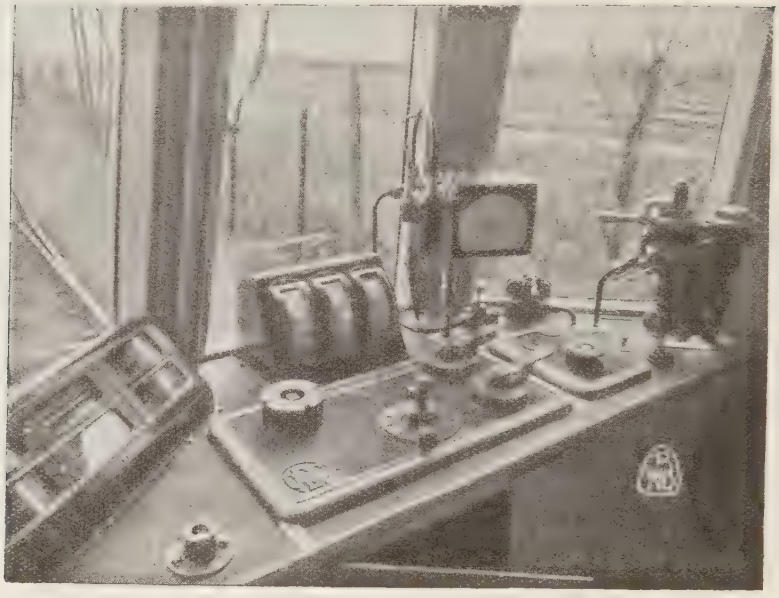

Fig. 58. — LA BRUGEOISE triplet railcar, Belgian National Rys. Co.

Fig. 59. — LA BRUGEOISE triplet, Belgian National Rys. Co.

S.E.M. electric transmission (8 units in service) (figs. 58 and 59).

The orders for these 8 sets were placed as follows: 5 were designed and built by the « Baume & Marpent Co. Ltd. »; three by the « La Brugeoise & Nicaise & Delcuve Co. Ltd ».

Among the 5 « Baume & Marpent » rakes were:

3 rakes equipped with two S.E.M. Carels 365/400-h.p. diesel engines, with S.E.M. electric transmission;

1 rake with two 450/550-h.p. Mercedes-Benz diesel engines, with A.C.E.C. electric transmission;

1 rake with two 400/440-h.p. Frichs diesel engines, with A.C.E.C. electric transmission.

The three « La Brugeoise » rakes are equipped with 410/450-h.p. Maybach diesel engines, with A.C.E.C. electric transmission.

229 seats.

Total weight under load: 148 t. (145 Engl. t.) (La Brugeoise), and 156 t. (153.5 Engl. t.) (Baume-Marpent).

Maximum speed: 150 km. (93 miles) an hour.

Belgian National Light Railways Company.

The *Belgian National Light Railways Company* has a number of four-wheeled railcars in service, some with Brossel 100-h.p. petrol engines, and the others with 90-h.p. Gardner diesel engines.

BELGIUM.

Transmission.		Maximum speed on the level km. *(miles)*.	Number of wheels.	Weight empty, in working order, t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*. (1st. Oct. 1936).	Kind of service.
Type.	Builders.								
In service.									
3 Sentinel railcars with one 100-H.P. Sentinel steam engine.									
eam.	Sentinel.	85 *(52.8)*	8	34.1 *(32.9)*	Rev.	62	1930	574 688 *(357 170)*	Local.
1 Birmingham railcar with one 175-H.P. Yorkshire steam engine.									
eam.	Yorkshire.	70 *(43.5)*	8	43.7 *(43.0)*	Rev.	82	1933	258 564 *(160 698)*	Local.
1 « Société Anonyme Métallurgique Nivelles » railcar with two 125-H.P. Sentinel steam engines.									
eam.	Sentinel.	90 *(56)*	8	47.5 *(46.8)*	Rev.	71	1936	21 426 *(13 316)*	Local.
3 E.V.A. railcars with one 175-H.P. Maybach diesel engine.									
ech.	Maybach.	65 *(40.4)*	8	40.3 *(39.7)*	Rev.	92	1930	537 189 (333 865)	Local.
14 « Société Anonyme La Brugeoise » railcars with one 175-H.P. Maybach diesel engine.									
ech.	Maybach.	80 *(50)*	8	33.7 *(33.2)*	Rev.	104	1933	302 619 *(192 429)*	Local.
5 Ganz railcars with one 120-H.P. Ganz diesel engine.									
ech.	Ganz.	72 *(45)*	4	15.7 *(15.4)*	Rev.	106	1934	155 503 *(96 645)*	Local.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. *(miles)*.	Number of wheels.	Weight empty, in working order, t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*. (1st. Oct. 1936).	Kind of service.
1 « La Dyle » railcar with one 140-H.P. M.A.N. diesel engine.									
Mech.	T.A.G. (Berlin).	80 *(50)*	4	16.7 *(16.3)*	Rev.	60	1934	94 428 *(58 687)*	Local.
1 « La Brugeoise » railcar with one 210-H.P. Maybach diesel engine.									
Mech.	Maybach.	80 *(50)*	8	31.4 *(30.9)*	Rev.	104	1934	156 324 *(97 136)*	Local.
1 S.E.M. Braine-le-Comte railcar with one 220-H.P. Carels-Ganz diesel engine.									
Mech.	Ganz.	80 *(50)*	8	29.9 *(29.4)*	Rev.	100	1935	60 241 *(37 432)*	Local.
1 « Baume et Marpent » railcar with one 320-H.P. Carels-Ganz diesel engine.									
Mech. (Automobile).	S.L.M.	85 *(52.8)*	8	38.2 *(37.6)*	Rev.	70	1936	62 280 *(38 700)*	Local.
1 « Forges et Fonderies de Haine-St-Pierre » railcar with one 330-H.P. Mercedes-Benz Diesel engine.									
Mech.	S.L.M. Winterthur.	90 *(56)*	8	36.3 *(35.7)*	Rev.	70	1936	16 020 *(9 950)*	Local.
1 A.S.E.A. railcar with one 200-H.P. Burmeister & Wain diesel engine.									
Elec.	A.S.E.A.	80 *(50)*	8	43.7 *(43)*	Rev.	74	1932	450 752 *(280 090)*	Local.
1 « La Brugeoise » railcar with one 210-H.P. Maybach engine.									
Elec.	A.C.E.C. (Charleroi).	80 *(50)*	8	32.3 *(31.8)*	Rev.	104	1934	142 711 *(88 678)*	Local.
1 « La Brugeoise » twin railcar with one 410/450-H.P. Maybach engine.									
Elec.	Siemens-Gebus, Berlin.	150 *(93.2)*	12	72 *(71)*	Rev.	187	1934	146 953 *(91 315)*	Fast through.
3 « La Brugeoise » triple railcars with two 410/450-H.P. Maybach engines.									
Elec.	A.C.E.C. (Charleroi).	150 *(93.2)*	16	130.4 (129)	Rev.	229	1936	38 688 *(24 040)*	Fast through.
3 « Baume et Marpent » triple railcars with two 365/400-H.P. Carels-Ganz engines.									
Elec.	S.E.M. (Gent).	150 *(93.2)*	16	138 *(136)*	Rev.	229	1936	36 982 *(22 607)*	Fast through.
1 « Baume et Marpent » triple railcar with two 400/440-H.P. Frichs engines.									
Elec.	A.C.E.C. (Charleroi).	150 *(93.2)*	16	138 *(136)*	Rev.	229	1936	(*)	Fast through.

(*) *Note.* — Railcars put into regular service on October 4th, 1936.

Transmission.		Maximum speed on the level km. *(miles)*.	Number of wheels	Weight empty, in working order, t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*, (1st. Oct. 1936).	Kind of service.
Type.	Builders.								
1 « Baume et Marpent » triple railcar with two 450/550-H.P. Mercedes-Benz engines.									
Elec.	A.C.E.C. (Charleroi).	150 *(93.2)*	16	138 *(136)*	Rev.	229	1936	(*)	Fast through.

On trial or under construction.

None.

(*) *Note.* — Railcars put into regular service on October 4th, 1936.

SPAIN.

Madrid, Saragossa & Alicante Railways (M.Z.A.).

The M.Z.A. has 10 diesel railcars in service, and 14 under construction.

Cia Auxiliar de F.C. Beasain eight-wheeled railcar with one 410-H.P. diesel engine (4 units in service) (fig. 60).

One 410-H.P. Maybach diesel engine.

Brown-Boveri electric transmission.

Electro-pneumatic distant control for multiple-unit working.

Automatic couplers which couple up the brake pipes and connect the electric conductors.

Heating by independent oil-fired boiler. Special trailers can be hauled.

« La Maquinista » Terrestre y Maritima, Barcelona eight-wheeled railcar with one 250-H.P. diesel engine.

1 Burmeister & Wain 250-H.P. two-stroke diesel engine.

Geathom electric transmission.

Electro-pneumatic distant control when worked in multiple-units.

Automatic coupler coupling the brake pipes and connecting the electric conductors.

Fig. 60. — 410-H.P. railcar with two trailers, Madris-Saragossa-Alicante Rys.

SPAIN.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. *(miles)*.	Number of wheels.	Weight empty, in working order, metr. t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*.	Kind of service.
In service.									
M.Z.A.									
4 « C^ia Auxiliar de F.C. Beasain » railcars with one 410-H.P. Maybach diesel engine.									
Elec.	Brown-Boveri.	100 *(62)*	8	45 *(44.5)*	Rev. Twins. Trailer.	80	1935 1936	...	Through and Local.
4 « La Maquinista Terrestre y Maritima, Barcelona » railcar with one 250-H.P. 2-stroke Burmeister & Wain diesel engine.									
Elec.	Geathom.	90 *(56)*	8	45 *(44.5)*	Rev. Twins.	72	1936	...	Through and Local.
2 « Material Móvil y Construcciones, Saragossa » railcars with one 265-H.P. Renault diesel engine.									
Mech.	Renault.	107 *(66.4)*	8	32.5 *(32)*	Rev. Twins.	71	1936	...	Through and Local.
Under construction.									
4 « Material Móvil y Construcciones, Saragossa » railcars with one 265-H.P. Renault diesel engine.									
Mech.	Renault.	107 *(66.4)*	8	32.5 *(32)*	Rev. Twins.	71	...	...	...
6 « C^ia Auxiliar de F.C. Beasain » railcars with two 140-H.P. Fiat diesel engines.									
Mech.	Fiat.	100 *(62)*	8	...	Rev.	...	...	...	...
4 « Material Móvil y Construcciones, Saragossa » railcars with one 110-H.P. Renault diesel engine.									
Mech.	Renault.	90 *(56)*	4	...	Rev.	...	...	...	...

FRANCE.

Main-line Railways.

On the 1st October 1936, the French main-line Railways had 510 railcars in service and 166 on trial or under construction.

They went on developing new types so as to promote competition as regards the solution of technical problems and thus encourage further progress; in addition they have ordered large numbers of types already tried out or improved types derived from earlier types. Thus, amongst the railcars put into service since the 1st January 1935, 69 are of 18 new types; among those on trial or under construction, there are 11 new types.

Of the whole stock of 671 railcars, 552 will belong to relatively important classes.

The table hereafter shows the general distribution between types of this stock of 671 railcars.

	In service on October 1st, 1936.	Under construction on October 1st, 1936.
Petrol railcars.		
Michelin railcars (with pneumatic tyres) :		
36-seater Michelines	26	None.
56-seater Michelines	39	6
96-seater Michelines	None.	2
Bugatti railcars :		
800-H.P. railcars (single or double)	12	None.
400-H.P. railcars	40	14
Diesel railcars.		
Renault railcars :		
4-wheeled railcars	12	...
2-bogie single railcars (which can be coupled up as twins or not)	166	10
3-bogie double railcars	7	8
Standard railcars with two 300-H.P. engines.	8	35
De Dietrich railcars :		
Railcars with two 110-H.P. engines	35	None.
Railcars with two 160-H.P. engines (which can be coupled up as twins or not)	18	22
Aciéries du Nord 280-H.P. railcars	18	5
Decauville railcars :		
Railcars with two 160-H.P. engine, and mechanical transmission	None.	2
Railcars with two 300-H.P. engines and electric transmission	4	5
S.O.M.U.A. railcars :		
Articulated railcars with one 280-H.P. (350 when supercharged) engine	7	4
Charentaise 8-wheeled railcars	19	None.
Berliet railcars with two 125-H.P. or 150-H.P. engines.	6	12
Franco-Belge 6-bogie triple railcars	6	4
Total of classes.	423	129
Prototypes on trial.	26	32
Prototypes tested but not developed subsequently	61	...
Total	510	161

The Alsace-Lorraine Rys. are developing their fast local services and their high-speed services (Strasbourg-Paris and Strasbourg-Lyons).

The Est Rys. divide the services to be worked by railcars into :

(1) Local services on secondary lines, giving an improved service by adding stops at level crossings and optional stops;

(2) Semi-express trains over lines where the local services will be worked by road motor vehicles;

(3) Express services to improve the connections between large cities.

The STATE RYS. are satisfied that the single light bogie vehicle (15 tons if carried on pneumatic tyres, and 25 to 30 tons on steel tyres) with excess power (300 to 500 H.P. diesel or petrol engines) capable of working at high speed (120 to 130 km. = 75 to 81 miles an hour), carrying 80 to 100 seated passengers is the most advantageous vehicle for the economical operation of fast local services or semi-through services, on main lines as well as on branch lines. It will become the more and more obvious that, in order to cope with traffic peaks, it will be necessary to couple together two otherwise single units, driven by one man, or run them as twins, each vehicle retaining its own driver.

Such a formula should evidently not be considered as exclusive; for fast services on main lines, there appear to be many opportunities for fast (140 km. = 87 miles an hour), comfortable, high-capacity (about 150 seats) railcars, which therefore will generally be multiple-units (2 or 3 bodies), carried on individual bogies, or partly on articulated (common) bogies.

The NORD RY. is developing its railcar services in place of stopping trains on secondary lines, and for this purpose orders Standard 600-H.P. railcars that can haul one or two ordinary wagons or a passenger coach of ordinary or special design. At the same time the Nord Railway is ordering railcars of smaller capacity for services where trailers are not necessary.

This Railway is also developing triple high-speed railcars carried on 6 bogies running at 140 km. (87 miles) an hour, and is considering the application of this solution with specially arranged bodies and lower maximum speed for the suburban traffic west of Paris.

The P.L.M. RYS. report that their tendencies are as follows :

(1) More frequent train services over

Fig. 61. — The Fives depot (French Nord Ry.) to which the FRANCO-BELGE triplets belong.

short or average distances by motor trains, with engines of average power (300 H.P.) with 60 to 80 seats, with which the timetables can be greatly improved.

(2) Increasing the stock belonging to centres covering lines in hilly country, by means of high-power railcars (600 H.P.), which can also haul a trailer.

(3) Purchasing specially designed trailers, of light construction.

(4) Developing high-speed services, worked by means of railcars, on cross-country (transverse) lines.

The P.O.-Midi Rys. now order only railcars seating at least 70 passengers and providing standing room for 30 to 40, with engines of about 500-H.P., which can haul a carriage or wagon, and be run in pairs if need be.

Experience has shown, indeed, that the railcar gives the best results when replacing steam trains on the less important lines. In addition the railcar is able to give sufficiently rapid and frequent services between important centres to enable passengers to make the return journey during the morning or in the afternoon.

8-wheeled Renault railcar with one 500-H.P. diesel engine (1 unit in service; 6 units under construction: Est-State).

1 Renault 16-cylinder V-type diesel engine developing 500 H.P. at 1 500 r.p.m.

Four-speed Renault mechanical transmission with electro-pneumatic control.

Two driver's compartments.

50 to 70 seats.

Weight: 35 t. (34.4 Engl. tons).

Maximum speed: 140 km. (87 miles) an hour.

Compressed-air brake operating brake blocks, and electro-magnetic brake.

Heating by exhaust gases.

Thanks to its reserve power, this railcar is capable of covering the local services as well as high-speed services, and can easily haul a trailer.

Renault 12-wheeled triple railcar with two 500-H.P. diesel engines (2 units under construction: State).

Each railcar consists of 3 bodies carried on 4 bogies; the centre body contains the engine room and luggage compartments and the two outer bodies provide the passenger accomodation.

The centre engine room has two Renault 500-H.P. 1 500 r.p.m., 16-cylinder V-type, diesel engines, each of which drives one of the articulated bogies through 4-speed mechanical transmission with electro-pneumatic control.

Two driver's compartments.

144 seats.

Weight: 95 t. (83.5 Engl. tons).

Maimum speed: 140 km. (87 miles) an hour.

Compressed-air brakes operating brake blocks, and electro-magnetic brake.

Heating by exhaust gases.

Renault eight-wheeled railcar with two 150-H.P. diesel engines (1 unit in service; 5 units under construction: State Rys.) (fig. 62).

Two 150-H.P. 6-cylinder Renault diesel engines placed in a central compartment and each driving one of the bogies.

4-speed mechanical transmission with electro-pneumatic control.

A central raised driver's compartment allowing the car to be driven in both directions.

68 seats.

Weight: 23 t. (22.6 Engl. tons).

Maximum speed: 120 km. (75 miles) an hour.

Jourdain-Monneret-Lockheed oleo-pneumatic drum brake.

Heating by exhaust gases.

96-seater 24-wheeled Micheline railcar carried on 12 pairs of wheels with one 400-H.P. petrol engine (2 units under construction: State).

One Panhard 12-cylinder V-type petrol engine developing 400 H.P. at 1 600 r.p.m., each end of the crank shaft driving one pair of wheels by mechanical transmission, (Daimler hydraulic clutch and Cotal electro-magnetic 4 speed gearbox) (fig. 63).

Fig. 62. — RENAULT railcar with two 150-H.P. RENAULT engines.

2 driver's compartments.

1 box-girder type body 30 m. (98′ 5 1/8″) long carried at each end by the pivots of 2 bogies and driven through longitudinal rods by a central motor bogie without pivot, having a large amount of lateral displacement.

96 seats.

Weight : 16.3 t. (16 Engl. tons).

Maximum speed : 135 km. (83.9 miles) an hour.

Westinghouse - Lockheed oleo - pneumatic drum brake.

Ventilating air heated by passing over radiators through which the engine cooling water is circulated.

32-wheeled triple Micheline railcar with two 250-H.P. engines (2 units under construction : State Rys.).

This railcar has 3 bodies carried on 4 bogies. The central unit has an engine room with :

2 Hispano 12-cylinder V-type petrol engines developing 250 H.P. at 3 000 r.p.m.

Mechanical transmission including two Daimler hydraulic clutches and 2 Cotal 2-speed electro-magnetic gearboxes.

2 driving compartments.

106 seats.

Weight : 25 t. (24.6 Engl. tons).

Maximum speed : 130 km. (80.8 Engl. tons) an hour.

Westinghouse-Lockheed oleo-pneumatic brake acting on drums.

Heating : Moreau-Fèbvre-Etat pulsated air system.

De Dietrich 8-wheeled railcar with two 160-H.P. diesel engines (18 units in ser-

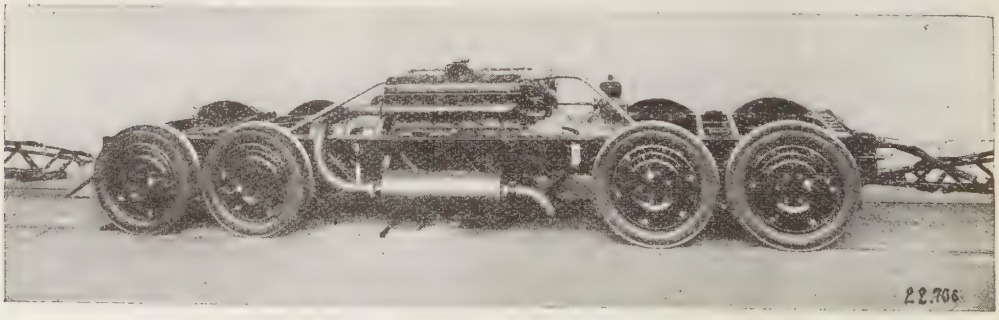

Fig. 63. — Motor bogie of 96-seater MICHELINE.

vice, 22 units on trial or under construction: Alsace-Lorraine, Est, State and P.L.M. Rys.) (fig. 64).

Two Saurer 6-cylinder diesel engines developing 160 h.p. at 1 500 r.p.m.

Mylius 4-speed mechanical transmission, preselective gear with pneumatic or electro-pneumatic control, according to whether the rail motor cars are or are not to be run in pairs.

2 driver's compartments.

60 to 80 seats.

Weight: 34 t. (33.5 Engl. tons).

Maximum speed: 120 km. (75 miles) an hour.

Westinghouse compressed-air brake acting on brake blocks proportionally to the vehicle speed.

Heating by exhaust gases.

Standard 4-wheeled railcar with two 300-h.p. diesel engines (8 units in service, 35 on trial or under construction: Est, Nord, P.O.-Midi Rys.) (fig. 65).

2 Renault diesel engines developing 300-h.p. at 1 500 r.p.m., and carried on the bogies.

Fig. 64. — De Dietrich 320-h.p. fast railcar of the French Est Rys.

Winterthur 5-speed mechanical transmission.

2 driver's compartments.

60 seats.

Weight in working order, loaded: 55 t. (54.1 Engl. tons).

Maximum speed: 120 km./h. A speed of 80 km. (50 miles) an hour is reached in 72 seconds.

Can haul trailers, of special design or not.

Heating by exhaust gases.

Aciéries du Nord railcar with one 280-h.p. diesel engine (18 units in service, 5 under construction: State, P.L.M. and P.O.-Midi Rys.).

1 Acenor 8-cylinder diesel engine developing 280 h.p. at 1 400 r.p.m.

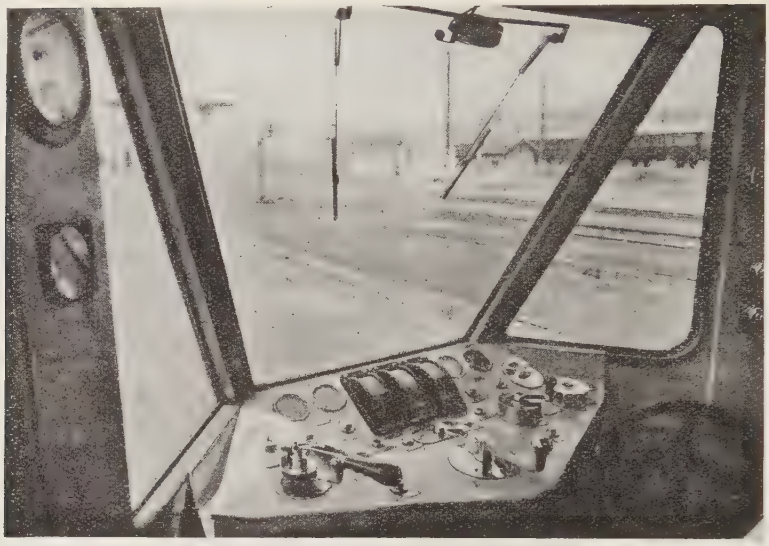

Fig. 65. — STANDARD railcar with two 265-H.P. engines. — Driver's stand.

Fig. 66. — BUGATTI triplet with four 200-H.P. engines (French State Rys.).

Winterthur 5-speed mechanical transmission.

2 driving compartments.

70 to 80 seats.

Weight: 36 t. (35.4 Engl. tons).

Maximum speed: 125 km. (77.7 miles) an hour.

Jourdain-Monneret-Lockheed oleo-pneumatic block brake.

Electro-magnetic brake.

Heating by exhaust gases.

Bugatti 48-wheeled triple railcar with four 200-H.P. petrol engines (2 units in service: State Rys.) (fig. 66).

Each railcar consists of 3 bodies, each on 2 bogies, i.e. 1 motor unit between two trailers.

The motor unit contains 4 Royal Bugatti 8 cylinder engines developing 200 H.P. at 2 500 r.p.m.; these engines are grouped in a central engine room, and arranged in lines parallel to the longitudinal centre line of the railcar.

Mechanical transmission, each engine having a Daimler hydraulic clutch, a 2-speed Cotal gear box and a reverse gear.

Raised central driver's compartment for driving the railcar in both directions.

2 driving axles on each bogie of the motor unit. Elastic wheels.

152 seats.

Weight: 70 t. (68.9 Engl. tons).

Maximum speed: 140 km. (87 miles) an hour.

Compressed air brake acting on drums.

Lorraine railcar with two 130 or 160-H.P. diesel engines (5 units in service, 3 under construction: Est and State Rys.).

2 Lorraine 6 cylinder diesel engines, developing 130 or 160 H.P. at 1 500 r.p.m.

Mechanical transmission with Wilson gearbox.

2 driver's compartments.

50 seats.

Weight: 24.5 t. (24.1 Engl. tons).

Maximum speed: 120 km. (75 miles) an hour.

Compressed-air brake acting on brake blocks covering the whole of the tyre, including the flange.

Heating by air conditioning on the Neu system.

Decauville railcars with two 300-H.P. diesel engines (intended for the Alpine lines) (4 units in service, 5 under construction: P.L.M.).

2 Saurer diesel engines developing 300 H.P. at 1 500 r.p.m.

Oerlikon electric transmission.

2 driver's compartments.

62 seats.

Weight: 41.5 t. (40.8 Engl. tons).

Maximum speed: 110 km. (68.35 miles) an hour.

Compressed air brake applying blocks on the tyres and on drums.

Heating by exhaust gases.

2 Decauville railcars, with 2 Saurer 140-H.P. diesel engines, and mechanical transmission are also in service on the Nord Ry., and 2 with two 160-H.P. Saurer diesel engines, with mechanical transmission, are under construction for the State Rys.

2 Alsthom-Soulé eight-wheeled railcars two 250-H.P. diesel engines (2 units under construction for the P.O.-Midi Rys.).

2 Alsthom-Ganz 6-cylinder engines, developing 250 H.P. at 1 300 r.p.m.

Alsthom-Royer electric transmission.

2 driver's compartments.

68 seats.

Weight empty: 50 t. (49.2 Engl. tons).

Maximum speed: 135 km. (83.9 miles) an hour.

These two railcars can run in pairs and haul an ordinary carriage weighing not more than 50 t.

Automatic block brake.

Electro-magnetic brake.

Heating of railcar by the exhaust gases, and of the trailer by an oil-fired steam boiler.

Berliet railcars with two 125 or 150-H.P. diesel engines (6 units in service, 12 under construction: P.L.M.).

Two 125-H.P. Berliet diesel engines for the units in service, and 150 H.P. engines for those under construction.

Alsthom electric transmission.

2 driver's compartments.

2 units are arranged as parcels vans (weight 35 t. = 34.4 Engl. tons; maximum speed: 120 km. = 75 miles an hour).

The others have 63 seats (weight 38 t. = 37.4 Engl. tons; maximum speed: 90 km. = 56 miles an hour).

Block brakes with oleo-pneumatic control.

Electro-magnetic brake.

Hot air heating on the Schnebeli system.

Brissonneau & Lotz eight-wheeled railcars with two 200-H.P. diesel engines (2 units under construction for the P.O.-Midi Rys.).

2 M.A.N. 6-cylinder diesel engines developing 200 H.P. at 1 200 r.p.m.

Brissonneau & Lotz electric transmission.

2 driver's compartments.

68 seats.

Weight empty: 40 t. (39.4 Engl. tons).

Maximum speed: 126 km. (78.3 miles) an hour.

These two railcars can run as twins and can haul a vehicle not exceeding 50 t. (49.2 Engl. tons) in weight when loaded.

Automatic brake acting on blocks.

Electro-magnetic brake.

Railcar heated by exhaust gases, and trailer by oil-fired steam boiler.

FRANCE.

Light railways and Colonial Railways.

Société Générale des Chemins de fer économiques.

This Company owns:

35 four-wheeled de Dion railcars with an 85 or 105 H.P. UNIC engine (mechanical transmission);

5 Brissonneau & Lotz 2-bogie railcars with one 105-H.P. Berliet diesel engine (Brissonneau & Lotz electric transmission).

It has under construction 1 de Dion 2-bogie railcar with a C.L.M. 150-H.P. diesel engine (mechanical transmission).

Régie Départementale des Tramways de l'Ain.

In service, 25 four-wheeled railcars 24 of which have petrol engines and mechanical transmission, and one a producer-gas engine; all these railcars can haul a trailer, and were built by Messrs. de Dion-Bouton.

Tunisian Railways Company.

The Tunisian Railways Co. has at the present time in service 6 Renault A.B.J. 265-H.P. railcars of the usual type (fig. 67), some of which are fitted with a kitchen. The Company has under construction 12 de Dietrich articulated railcars, each with 2 Saurer 200-H.P. 6-cylinders in line diesel engines; the mechanical transmission is of the Mylius 4-speed type. The units can be driven several coupled together. 84 seats in the 4 railcars without kitchen and 78 in those with one.

Maximum speed: 120 km. (75 miles) an hour.

Government General of Indo-China.

The Government General of Indo-China has just taken delivery of 6 two-bogie Renault A.B.H. railcars with one Renault diesel engine developing 265-H.P. at 1 500-r.p.m., for use on the very busy lines near Hanoi and Saigon.

Fig. 67. — RENAULT A.B.J. railcar of the Tunisian Railway Co.

Fig. 68. — Baudet-Donon-Roussel 260-h.p. railcar, French Nord Ry.

Indo-China & Yunnan Railways Company.

This Company put into service, in 1935, 5 Decauville railcars (three with two 140-h.p. Saurer diesel engines, and two with one 140-h.p. Saurer diesel engine), which have up to date run 30 000 to 110 000 km. (18 600 to 68 350 miles).

Damas-Hamah Railway and Extension.

This railway owns 4 de Dietrich bogie railcars each fitted with two 105-h.p. C.L.M. diesel engines, with Mylius transmission.

The cost per railcar-kilometre in 1935 was 1.73 francs, made up as follows:

Fuel	0.10 fr.
Lubricants	0.19 fr.
Maintenance and repairs.	1.11 fr.
Driving staff	0.21 fr.
Heating and lighting	0.04 fr.
Operating staff	0.08 fr.
	1.73 fr.

FRANCE.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. *(miles)*.	Number of wheels.	Weight empty, in working order, t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*. (1st. Oct. 1936).	Kind of service.
In service.									
9 Michelines, 24 seats, with one 95-H.P. Panhard petrol engine (Est, Nord, P.O.-Midi).									
Mech.	Panhard.	95 *(59)*	10	4.7 *(4.6)*	...	24	1932	247 000 *(153 500)*	Local. Semi-through.
26 Michelines, 36 seats, with one 220-H.P. Hispano petrol engine (Est, State, Nord).									
Mech.	Panhard.	100 *(62)*	12	7.5 *(7.4)*	Rev.	36	1933-1934	185 000 *(114 950)*	Local. Semi-through.
39 Michelines, 56 seats, with one 220-H.P. or 250-H.P. Hispano petrol engine (Est, State, Nord, P.L.M., P.O.-Midi).									
Mech.	Hispano.	100 *(62)*	16	8 *(7.9)*	Rev.	56	1934 1935 1936	86 000 *(53 400)*	Local. Semi-through.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. *(miles)*.	Number of wheels.	Weight empty, in working order. t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*. (1st. Oct. 1936).	Kind of service.
2 Michelines. 32 seats, with one 250-H.P. Hispano petrol engine (State).									
Mech.	Hispano.	120 *(75)*	12	7 *(6.9)*	...	32	1934	130 000 *(80 780)*	Rapides.
14 Renault railcars with one 85-H.P. Renault diesel engine (State).									
Mech.	Renault.	90 *(56)*	4	11 *(10.8)*	...	34	1930-31-32	130 000 *(80 780)*	Fast-local. Semi-through.
166 Renault railcars with one 220-H.P., 265-H.P. or 300-H.P. Renault diesel engine. (All Railways).									
Mech.	Renault.	120 *(75)*	8	27 *(26.6)*	Rev. Twins. (1935-36)	56, 48 or 76	1933-1934 1935 1836	129 000 *(80 160)*	Local. Semi-through.
12 Renault railcars with one 110-H.P. Renault diesel engine (State. Nord).									
Mech.	Renault.	90 *(56)*	4	9 *(8.9)*	Rev.	30 to 35	1934-1936	130 000 *(80 780)*	Local and newspapers.
1 Renault railcar with one 500-H.P. Renault diesel engine (State).									
Mech. with electro-pneumat. control.	Renault.	120 *(75)*	8	30 *(29.5)*	Rev. Trailer.	51	1936	112 000 *(69 600)*	Semi-through.
1 Renault railcar with two 150-H.P. Renault diesel engines (State).									
Mech. with electro-pneumat. control.	Renault.	120 *(75)*	8	23 *(22.6)*	Rev.	68	1936	19 000 *(11 800)*	Rapides.
1 Renault railcar with two 265-H.P. Renault diesel engines (Est).									
Mech. with electro-pneumat. control.	Renault.	140 *(87)*	8	37 *(36.4)*	Rev. Twins.	42	1936	15 000 *(9 300)*	Fast-local.
7 Renault double railcars with two 265-H.P. or 300-H.P. Renault diesel engines (State, Est, P.L.M., P.O.-Midi).									
Mech. with electro-pneumat. control.	Renault.	140 *(87)*	12	58 *(57)*	Rev. Trailer.	86 to 113	1934 1935 1936	94 000 *(58 400)*	Rapides.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. *(miles)*.	Number of wheels.	Weight empty, in working order, t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*. (1st. Oct. 1936).	Kind of service.
1 Renault triple railcar with two 500-H.P. Renault diesel engines (State).									
Mech. with electro-pneumat. control.	Renault.	120 *(75)*	16	95 *(93.5)*	Rev.	144	1936	12 000 *(7 460)*	Rapides.
8 Standard railcars with two 300-H.P. Renault diesel engines (Nord).									
Mech.	Winterthur.	120 *(75)*	8	40 *(39.5)*	Rev. Trailer.	60	1936	23 000 *(14 290)*	Local. Semi-through.
35 De Dietrich railcars with two 110-H.P. C.L.M. diesel engines (Alsace-Lorraine, Est, State, P.O.-Midi).									
Mech. (one hydr.).	Mylius-Voith.	100 *(62)*	8	26 *(25.6)*	Rev.	60 to 75	1933-1934 1935 1936	130 000 *(80 780)*	Local. Semi-through.
18 De Dietrich railcars with two 150 or 160-H.P. Saurer diesel engines. (Est, State, P.L.M.).									
Mech. with electro-pneumat. control.	Mylius.	120 *(75)*	8	34 *(33.4)*	Rev. Twins.	60 to 80	1935-1936	46 000 *(28 600)*	Local. Semi-through.
4 A.D.N. railcars with one 170-H.P. M.A.N. diesel engine (P.L.M., P.O.-Midi).									
Mech.	A.D.N.	100 *(62)* 110 *(68.3)*	8	35 *(34.5)*	Rev.	73	1933 1934	88 000 *(54 680)*	Local. Semi-through.
2 A.D.N. railcars with one 250-H.P. M.A.N. diesel engine (Nord).									
Electr.	1 A.S.E.A. 1 Jeumont.	100 *(62)*	8	30 *(29.5)*	Rev.	66	1934	122 000 *(75 800)*	Local.
18 A.D.N. railcars with one 280-H.P. M.A.N. or Acenor diesel engine (State, P.L.M., P.O.-Midi).									
Mech.	Winterthur.	120 to 130 *(75 to 80.8)*	8	36 *(35.6)*	Rev.	74 to 81	1934-1935 1936	50 000 *(31 070)*	Local. Semi-through.
12 Bugatti railcars with four 200-H.P. Bugatti petrol engines (State 9, P.L.M. 3 with trailer).									
Mech. with hydr. clutch.	Bugatti.	140 *(87)*	16 and 32	32 and 54 *(31.5 and 53.1)*	Rev. Trailer.	60 and 74	1933-1934 1935 1936	144 000 *(89 480)*	Rapides.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. *(miles)*.	Number of wheels.	Weight empty, in working order, t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*. (1st. Oct. 1936).	Kind of service.
		40 Bugatti railcars with two 200-H.P. Bugatti petrol engines (Alsace-Lorraine, State, P.L.M.).							
Mech. with hydr. clutch.	Bugatti-Cotal.	140 *(87)*	16	26 *(25.6)*	Rev.	44-52 and 73	1935 1936	61 000 *(37 900)*	Rapides.
		2 Bugatti triple railcars with four 200-H.P. Bugatti petrol engines (State).							
Mech. with hydr. clutch.	Bugatti-Cotal.	140 *(87)*	48	70 *(68.9)*	Rev.	152	1936	24 000 *(14 900)*	Rapides.
		6 Franco-Belge triple railcars with two 410-H.P. Maybach diesel engines (Nord).							
Electr.	Gebus Franco-Belge Jeumont.	150 *(93)*	24	120 *(118)*	Rev.	144	1934	98 000 *(60 900)*	Rapides.
		5 Charentaise railcars with one 110-H.P. Peugeot-Junkers diesel engine (P.O.-Midi).							
Mech.	Minerva.	90 *(56)*	4	9 *(8.9)*	Rev.	45	1932-1934	84 000 *(52 200)*	Local.
		19 Charentaises « Pauline 2 » railcars with one 80-H.P. Peugeot-Junkers diesel engine (Als.-Lorr., State, P.L.M., P.O.-Midi).							
Mech.	Minerva.	90 *(56)*	8	10 *(9.8)*	Rev.	50 to 60	1933-1934	199 000 *(123 650)*	Local.
		2 Charentaise railcars with one 120-H.P. M.A.N. diesel engine (Est).							
Mech.	Minerva.	100 *(62)*	8	18 *(17.8)*	Rev.	56	1934	169 000 *(105 000)*	Local.
		2 S.O.M.U.A. railcars with one 80-H.P. Peugeot-Junkers diesel engine (P.L.M.).							
Mech.	S.O.M.U.A.	90 *(56)*	4	11.7 *(11.5)*	...	40	1933	80 000 *(49 700)*	Local.
		2 S.O.M.U.A railcars with one 210-H.P. M.A.N. diesel engine and 1 with one 210-H.P. Panhard producer-gas engine (State).							
Mech.	S.O.M.U.A.	90 *(56)*	6	28.5 *(28.1)*	Rev. Trailer.	75	1934	48 000 *(29 800)*	Local.
		7 S.O.M.U.A. articulated railcars with one M.A.N. 280-H.P. (or supercharged 350-H.P.) diesel engine (P.L.M.).							
Mech.	S.O.M.U.A.	120 *(75)*	10	41 *(40.4)*	Rev.	76	1936	19 000 *(11 800)*	Local. Semi-through.

Transmission.		Maximum speed on the level km. *(miles)*.	Number of wheels.	Weight empty, in working order, t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*. (1st. Oct. 1936).	Kind of service.
Type	Builders.								
8 « Compagnie Générale de Construction » railcars with one 140-H.P. M.A.N. diesel engine (P.L.M. and State).									
Mech.	C^ie^ G.C.	90 (56)	4	18 *(17.8)*	Rev.	44	1933-1934	99 000 *(61 500)*	Local. Semi-through.
8 Baudet-Donon-Roussel railcars with one 110-H.P. Peugeot-Junkers diesel engine (P.L.M., P.O.-Midi).									
Mech.	Glaenzer-Spicer. Cotal gear box.	90 (56)	4	12.5 *(12.3)*	Rev. Twins.	40	1934	88 000 *(54 680)*	Local.
2 Baudet-Donon-Roussel railcars with two 140-H.P. Saurer diesel engines (Nord) (fig. 68).									
Mech.	Cotal.	100 *(62)*	8	26 *(25.6)*	Rev.	65	1935	95 000 *(59 000)*	Local.
2 Baudet-Donon-Roussel railcars with one 135-H.P. Berliet diesel engine (Est).									
Mech.	Cotal.	100 *(62)*	4	18 *(17.8)*	Rev. Twins.	46	1935	79 000 *(48 470)*	Local.
2 Decauville railcars with two 140-H.P. Saurer diesel engines (Nord).									
Mech.	Winterthur.	100 *(62)*	8	26 *(25.6)*	Rev.	64	1934	86 000 *(53 440)*	Local.
4 Decauville railcars with two 300-H.P. Saurer diesel engine (P.L.M.).									
Elec.	Oerlikon.	110 *(68.3)*	8	37 *(36.4)*	Rev. Trailer.	66	1936	12 000 *(7 460)*	Local. Semi-through.
2 « C^ie^ française de Matériel de Ch. de fer » railcars with one 140-H.P. Saurer diesel engine (P.L.M.).									
Mech.	C^ie^ Fr. Mat. Ch. fer.	90 (56)	4	17.4 *(17.2)*	Rev.	40	1934	99 000 *(61 500)*	Local.
2 « C^ie^ française de Matériel de Ch. de fer » railcars with two 140-H.P. Saurer diesel engines (Nord).									
Elec.	Oerlikon.	105 *(65.3)*	12	30 *(29.5)*	Rev.	62	1935	129 000 *(80 160)*	Local. Semi-through.
2 Delaunay-Belleville railcars with one 65-H.P. Delaunay diesel engine (P.L.M.).									
Mech.	Delaunay-Belleville.	90 (56)	4	11.7 *(11.5)*	Not. rev.	40	1935	6 000 *(3 730)*	Local.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. *(miles)*.	Number of wheels.	Weight empty, in working order. t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*. (1st. Oct. 1936).	Kind of service.
2 Batignolles-Bacalan railcars with two 140-H.P. Saurer diesel engines (Est).									
Mech.	Winterthur.	100 *(62)*	8	37 *(36.4)*	Rev.	60	1935	85 000 *(52 800)*	...
4 Société Centrale de Chemins de fer railcars with one 125-H.P. Berliet diesel engine (Est).									
Mech.	Minerva.	90 (56)	8	13.5 *(13.3)*	Not. rev.	49	1936	42 000 *(26 100)*	Local.
5 Lorraine railcars with two 130-H.P. Lorraine diesel engines (Est).									
Mech.	Wilson.	100 *(62)*	8	28 *(27.6)*	Rev.	47 to 50	1936	42 000 *(26 100)*	Local. Semi-through.
2 Berliet railcars and 4 Berliet rail motor vans with two 125-H.P. or 150-H.P. Berliet engines (P.L.M.).									
Elec.	Alsthom.	90 and 120 *(56 and 75)*	8	38 *(37.6)*	Rev. Trailer. Twins.	63 (rail-cars).	1935	59 000 *(36 620)*	Local. Semi-through. Parcels.
1 Atelier du Nord de la France steam railcar with two 150-H.P. Sentinel engines (Nord).									
Mech.	...	95 *(59)*	8	44 *(43.3)*	Rev.	65	1935	67 000 *(41 630)*	Local.
1 Dunlop-Fouga railcar with one 135-H.P. Maybach diesel engine (P.O.-Midi).									
Mech.	Winterthur.	100 *(62)*	16	17 *(16.8)*	Rev.	49	1935	45 000 *(27 960)*	...
On trial or under construction.									
Six 56-seater Michelines with one 250-H.P. Hispano petrol engine (State, Est).									
Two 96-seater Michelines with one 400-H.P. Panhard petrol engine (State).									
Mech.	Panhard. Cotal.	120 *(75)*	24	16 *(15.8)*	Rev.	96	...	...	...
2 triple Michelines with two 250-H.P. Hispano petrol engines (State).									
Mech.	Cotal.	130 *(81.5)*	32	25 *(24.6)*	Rev.	106	...	...	...
10 Renault railcars with one 300-H.P. Renault diesel engine (Alsace-Lorraine, Est, State).									
8 Renault double railcars with two 265-H.P. or 300-H.P. Renault diesel engines (State, Est, P.O.-Midi).									

Transmission.		Maximum speed on the level km. *(miles)*.	Number of wheels.	Weight empty, in working order. t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*.	Kind of service.
Type.	Builders.								
6 Renault railcars with one 500-H.P. Renault diesel engine (State, Est).									
5 Renault railcars with two 150-H.P. Renault diesel engines (State).									
1 Renault triple railcar with two 500-H.P. Renault diesel engines (State).									
35 Standard railcars with two 300-H.P. engines (Est, Nord, P.O.-Midi).									
22 De Dietrich railcars with two 160-H.P. Saurer diesel engines (Als.-Lorr., Est, State, P.L.M.).									
2 De Dietrich railcars with two 250-H.P. C.L.M. diesel engines (State, P.L.M.).									
Mech.	Mylius.	120 *(75)*	8	36 *(35.4)*	Rev. Trailer.	...	...	...	...
3 De Dietrich railcars with one 210-H.P. Panhard producer-gas engine (State).									
Mech.	Mylius.	120 *(75)*	8	32 *(31.4)*	Rev.	54	...	...	...
5 A.D.N. railcars with one 280-H.P. Acenor diesel engine (P.O.-Midi).									
14 Bugatti railcars with two 200-H.P. Bugatti petrol engines (State, P.L.M.).									
4 Franco-Belge triplets with two 410-H.P. Maybach diesel engines (Nord).									
4 Charentaise railcars with two 140-H.P. Saurer diesel engines (State).									
Mech.	Minerva.	120 *(75)*	8	25 *(24.6)*	Rev.	82	...	...	...
4 S.O.M.U.A. articulated railcars with one 280-H.P. (or 350-H.P. supercharged) M.A.N. diesel engine (P.L.M.).									

Transmission.		Maximum speed on the level km. *(miles)*.	Number of wheels.	Weight empty, in working order; t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*.	Kind of service.
Type.	Builders.								
2 Decauville railcars with two 160-H.P. Saurer diesel engines (State).									
Mech.	Winterthur.	130 *(80.8)*	8	26 *(25.6)*	Rev. Twins.	73	...	...	...
5 Decauville railcars with two 300-H.P. Saurer diesel engines (P.L.M.).									
1 Lerraine railcar with two 160-H.P. Lorraine diesel engines (State).									
12 Berliet railcars with two 150-H.P. Berliet engines (P.L.M.).									
2 Corpet-Louvet railcars with two 250-H.P. Frichs diesel engines (State).									
Elec.	Jeumont.	120 *(75)*	8	54 *(53.1)*	Rev. Trailer.	65	...	...	...
2 Brissonneau & Lotz railcars with two 200-H.P. M.A.N. diesel engines (P.O.-Midi).									
Elec.	Brisonneau.	130 *(80.8)*	8	40 *(39.4)*	Rev. Twins.	68	...	...	...
2 Alsthom-Soulé railcars with two 250-H.P. Alsthom diesel engines (P.O.-Midi).									
Elec.	Alsthom.	135 *(83.9)*	8	45 *(44.4)*	Rev. Twins. Trailer.	68	...	...	...
2 Ateliers du Nord de la France steam railcars with two 200-H.P. Sentinel engines (Est).									
Mech.	...	100 and 140 *(62 and 87)*	8	43 and 47 *(42.4 and 46.4)*	Rev. Trailer.	60 to 65	...	...	...

NETHERLANDS.

At the beginning of 1933, the *Netherlands Railways* ordered 40 triple railcars (fig. 69) : 35 equipped with two 410-H.P. Maybach diesel engines, and 5 with two 350-H.P. Ganz diesel engines.

28 sets were put into service in 1934 at the same moment. Unfortunately certain difficulties occurred with the Maybach engines which considerably interfered with the working.

The Maybach engines, which worked without any trouble for the first 20 000 km. (12 400 miles), began to show abnormal wear in the roller bearings, especially between this distance and about 30 000 km. (18 600 miles); the play in the roller bearings became so great that failures occurred at various points.

Fig. 69. — Triple railcar, Netherlands State Railways.

These defects were attributed first of all to the fact that the diesel engines developed too high a torque at speeds below the normal running speed, that the fuel feed was irregular, and that the lubricating oil used was unsuitable. The method of supplying the fuel to the pumps was altered and improved, and the lubricating oil replaced by another which has given quite satisfactory results. No alteration was made in the electric transmission except that the minimum working power condition (at 800 r.p.m.) was eliminated.

Systematic tests on the test bench showed that the crank shaft of the engine set up excessive bending vibrations and, as regards the damage to the crank shaft bearings, the causes of failure given above were only secondary, the main cause being the overloading under the combined effect of the inertia forces, combustion pressures, and vibrations.

As a result of these tests, the builder balanced the crank shafts by means of counterweights.

In addition, improvements were made to the fuel pumps and the injectors, as a result of which the maximum combustion pressure and the rate of increase of the pressure (which were rather high) were reduced.

At the present time 26 rakes equipped with Maybach engines with counter-balanced crank shafts and 4 rakes with Ganz engines are in service, these rakes covering monthly about 300 000 km. (186 000 miles).

Several Maybach engines with counter-balanced crank shafts, put into service in September 1935, have now run 100 000 km. (62 000 miles) without any trouble and there is every reason for thinking that the difficulties have been overcome.

After running about 55 000 km. (34 200 miles) the engines are carefully examined as regards cylinders and pistons. A thorough repair is given after 100 000 km. (62 000 miles).

NETHERLANDS.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. *(miles)*.	Number of wheels.	Weight empty, in working order. t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*.	Kind of service.
In service.									
13 two-bogie railcars with two 75-H.P. (approx.) petrol engines. 7 two-bogie railcars with two 115-H.P. (approx.) petrol engines.									
Mech.	N.A.G. and Deutsche Werke, Kiel.	75 *(46.6)*	8	32 to 45 *(31.5 to 44.3)*	Rev. Twins. Trailer.	65 to 76	1923 to 1929	252 000 to 623 000 *(156 600 to 387 100)*	Local.
6 Allan railcars with one 115-H.P. Stork-Ganz diesel engine.									
Mech.	Deutsche Getriebe.	60 *(37.3)*	4	19.5 *(19.2)*	Rev. Twins.	40	1929	169 400 *(105 260)*	Local.
8 railcars of various designs with one 115-H.P. Thomassen-Frichs engine.									
Mech.	Deutsche Getriebe.	50 *(31)*	4	18.5 *(18.2)*	Rev.	43	1927	249 000 *(154 700)*	Local.
35 triple railcars on 4 bogies, with two 410-H.P. Maybach diesel engines.									
Elec.	Heemaf Brown-B.	140 *(87)*	20	98.5 *(97,0)*	Rev.	160	1934	...	Semi-through. Fast expr.
5 triple railcars on 4 bogies with two 350-H.P. Stork-Ganz diesel engines.									
Elec.	Smit-Westing-house.	140 *(87)*	20	107 *(105.3)*	Rev.	160	1934	...	Semi-through. Fast expr.
Under construction.									
8 railcars with two 150-H.P. diesel engines (5 will be equipped with Stork-Ganz and 3 with Thomassen-Frichs engines).									
Mech.	Deutsche Getriebe.	120 *(75)*	8	45 *(44.3)*	Rev. Twins.	71	...	...	Local and semi-through.

ITALY.

The earliest railcars with internal combustion engines were put into service in Italy in 1927, but their real development only began about 1931.

The *Italian State Railways*, on the 1st November 1936, had 252 rail motor cars in service :

140 with petrol engines and mechanical transmission;

107 with diesel engines and mechanical transmission;

5 with diesel engines and electric transmission.

They have under test or under construction 134 railcars :

128 with diesel engines and mechanical transmission;

3 with diesel engines and hydraulic transmission;

3 with steam engines.

Fiat 2-bogie railcars with two 75-H.P. *petrol engines* (49 units in service) (fig. 70).

2 Fiat 6-cylinder petrol engines developing 75 H.P. at 2 000 r.p.m.

A radiator at each end of the coach.

Fiat mechanical transmission with pneumatic control.

56 seats.

Weight empty : 18 t. (17.7 Engl. tons).

Maximum speed : 110 km. (68.3 miles) an hour.

Pneumatically controlled clasp brake and hand brake.

Heating by exhaust gases.

Fiat 2-bogie railcars with two 75-H.P. *diesel engines* (69 units in service, 40 under construction).

Two Fiat 6-cylinder diesel engines, developing 75 H.P. at 1 600 r.p.m.

A radiator at each end of the car.

Fiat mechanical transmission with pneumatic control.

56 seats.

Weight empty : 20 t. (19.7 Engl. tons).

Maximum speed : 110 km. (68.3 miles) an hour.

Pneumatically-controlled clasp brake and hand brake.

Heating by exhaust gases.

Fiat 2-bogie railcars with two 145-H.P. diesel engines (25 units in service).

2 Fiat 6-cylinder diesel engines, developing 145 H.P. (fig. 71) at 1 700 r.p.m.

A radiator at each end of the car.

Fig. 70. — Building railcars in the Fiat Works.

Fig. 71. — A.L.N. 40 FIAT 290-H.P. railcar (Italy).

Fig. 72. —A.L.N. 56 BREDA railcar (Italy).

Fiat mechanical transmission, with pneumatic control.

40 seats (17 first-class, and 23 2nd-class). Restaurant.

Weight empty: 28 t. (27.6 Engl. tons)

Maximum speed: 130 km. (80.8 miles) an hour.

Pneumatically-controlled clasp brake and hand brake.

Heating by exhaust gases.

Breda 2-bogie railcars (fig. 72) with two 140-H.P. petrol engines (10 units in service).

2 Breda 6-cylinder petrol engines developing 140 H.P. at 2 400 r.p.m.

Radiator at each end of the coach.

Breda mechanical transmission, Wilson type gear box, with pneumatic control and hand control.

56 seats.

Weight empty: 22 t. (21.65 Engl. tons).

Maximum speed: 140 km. (87 miles) an hour.

Brake acting on drums, pneumatically and hand-controlled.

Heating by the engine cooling water.

Breda 2-bogie railcars with one 125-H.P. diesel engine (3 units in service).

1 Breda 6-cylinder diesel engine developing 125 H.P. at 2 000 r.p.m.

Radiator under the roof of the vehicle.

Breda mechanical transmission, Wilson gearbox, pneumatically and hand-operated

58 seats.

Weight empty: 15 t. (14.8 Engl. tons).

Maximum speed: 105 km. (65.25 miles) an hour.

Brake drums pneumatically and hand-controlled.

Heating by exhaust gases.

ITALY.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. *(miles)*.	Number of wheels.	Weight empty, in working order. t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*. (1st. Nov. 1936).	Kind of service.
In service.									
3 Cemsa railcars with one 100 or 160-H.P. petrol engine.									
Mech.	C.E.M.S.A.	50 *(31)*	8	18 to 25 *(17.7 to 24.6)*	Rev. Twins. Trailer.	45 to 70	1927 1928 1929	100 000 to 150 000 *(62 000 to 93 200)*	Local.
4 Fiat railcars with one 180-H.P. Fiat diesel engine.									
Elec.	Brown-Boveri.	55 *(34.2)*	8	44 *(43.3)*	Rev. Twins. Trailer.	30 to 38	1929	50 000 to 100 000 *(31 000 to 62 000)*	Local.
1 F.S. railcar with 150-H.P. M.A.N. diesel engine.									
Elec.	F.S.	60 *(37.3)*	8	34 *(33.5)*	Rev. Twins. Trailer.	45	1931	50 000 *(31 000)*	Local.

Transmission.		Maximum speed on the level km. *(miles)*.	Number of wheels.	Weight empty, in working order, t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*. (1st. Nov. 1936).	Kind of service.
Type.	Builders.								
2 Fiat railcars with one 65-H.P. Fiat petrol engine.									
Mech.	Fiat.	58 *(36)*	4	7 *(6.9)*	Trailer.	25	1932	125 000 *(77 670)*	Local.
15 Fiat railcars with one 120-H.P. Fiat petrol engine.									
Mech.	Fiat.	110 *(68.3)*	8	14 *(13.8)*	Rev.	48	1933	175 000 *(108 750)*	Express.
48 Fiat railcars with one 120-H.P. petrol engine.									
Mech.	Fiat.	100 *(62)*	8	17 *(16.7)*	Rev.	64	1934	150 000 *(93 200)*	Express.
9 Fiat railcars with two 120-H.P. Fiat petrol engines.									
Mech.	Fiat.	130 *(80.8)*	8	22 *(21.65)*	Rev.	80	1934	250 000 *(157 350)*	Express.
49 Fiat railcars with two 75-H.P. Fiat petrol engines.									
Mech.	Fiat.	110 *(68.3)*	8	18 *(17.7)*	Rev.	56	1935	75 000 to 150 000 *(46 600 to 93 200)*	Express.
9 Fiat railcars with two 75-H.P. Fiat diesel engines.									
Mech.	Fiat.	110 *(68.3)*	8	20 *(19.7)*	Rev.	56	1934	120 000 *(74 560)*	Express.
60 Fiat railcars with two 75-H.P. Fiat diesel engines.									
Mech.	Fiat.	110 *(68.3)*	8	20 *(19.7)*	Rev.	56	1936	...	Express.
25 Fiat railcars with two 145-H.P. Fiat diesel engines.									
Mech.	Fiat.	130 *(80.8)*	8	28 *(27.6)*	Rev.	40	1936	10 000 to 30 000 *(6 210 to 18 640)*	Express.
10 Breda railcars with two 140-H.P. Breda petrol engines.									
Mech.	Breda.	140 *(87)*	8	22 *(21.6)*	Rev.	56	1935	60 000 *(37 300)*	Express.
10 Breda railcars with two 125-H.P. Breda diesel engines.									
Mech.	Breda.	140 *(87)*	8	23 *(22.6)*	Rev.	56	1935	90 000 *(55 900)*	Express.
3 Breda railcars with one 125-H.P. Breda diesel engine.									
Mech.	Breda.	105 *(65.3)*	8	15 *(14.8)*	Rev.	58	1936	30 000 *(18 640)*	Express.

Transmission. Type.	Transmission. Builders.	Maximum speed on the level km. *(miles)*.	Number of wheels.	Weight empty, in working order, t. *(Engl. tons)*.	Reversibility. Twin coaches or multiple-unit. Trailer.	Number of seats including tip-up.	Year put into service.	Distance run per vehicle, km. *(miles)*. (1st. Nov. 1936).	Kind of service.
		2 Fiat rail motor vans with one 120-H.P. Fiat petrol engine.							
Mech.	Fiat.	90 *(56)*	8	15 *(14.8)*	Rev.	...	1934	80 000 *(50 000)*	Express.
		2 Breda rail motor vans with one 100-H.P. Breda petrol engine.							
Mech.	Breda.	80 *(50)*	8	16 *(15.7)*	Rev.	...	1935	20 000 *(12 430)*	Express.
		On trial or under construction.							
		40 Fiat railcars with two 75-H.P. Fiat petrol engines.							
Mech.	Fiat.	110 *(68.3)*	8	20 *(19.7)*	Rev.	56	...	...	...
		5 Fiat railcars with two 115-H.P. Fiat diesel engines.							
Mech.	Fiat.	70 *(43.5)*	8	23 *(22.6)*	Rev.	56	...	...	...
		80 Breda railcars with two 125-H.P. Breda diesel engines.							
Mech.	Breda.	140 *(87)*	8	...	...	...	...	...	...
		3 Officine Mecc. Milano railcars with two 125-H.P. O.M. diesel engines.							
Hydr.	O.M.	120 *(75)*	8	24 *(23.6)*	Rev.	72	...	...	...
		3 Officine Mecc. Milano railcars with two 110-H.P. steam engines.							
Hydr.	O.M.	120 *(75)*	8	24 *(23.6)*	Rev.	72	...	...	...
		3 Ansaldo railcars with two 150 H.P. Ansaldo diesel engines.							
Mech.	Ansaldo.	130 *(80.8)*	8	23 *(22.6)*	Rev.	56	...	...	...

PORTUGAL.

In addition to 2 Michelines with 85-H.P. Panhard engines, reported in 1935, and which have now run over 140 000 km. (87 000 miles) the Mozambique Colony has in service two Michelines with 150-H.P. Hispano-Suiza engines.

TABLE I. – Characteristics of the principal engines in

Number.	ENGINE	Licensee, if any.	Horse-power nominal.	Horse-power maximum.	R. p. m. nominal
1	FIAT	Built in Italy.	75	80	1 70
2	FIAT	Built in Italy.	75	80	2 00
3	C. L. M., 85 L. C. 3, 2-stroke	Built in France (Junker licence).	80	88	1 50
4	MERCEDES-BENZ-UNIC	Built in France (Mercedes-Benz licence).	85	95	1 70
5	GARDNER-MIESSE	Built in Belgium (Gardner licence).	90	96	1 60
6	ARMSTRONG-WHITWORTH	Built in England (Saurer licence).	95	105	1 50
7	BROSSEL-MIESSE	Built in Belgium.	100	110	1 65
8	GARDNER	Built in England.	102	...	1 70
9	C. L. M. 85 L. C. 4, 2-stroke	Built in France (Junker licence).	105	119	1 50
10	MERCEDES-BENZ-UNIC	Built in France (Mercedes-Benz licence).	105	120	1 50
11	GANZ	Built in Hungary.	110	130	1 00
12	RENAULT, 6 cylinders	Built in France.	110	120	1 50
13	STORK-GANZ	Built in Holland (Ganz licence).	115	125	1 20
14	THOMASSEN-FRICHS	Built in Holland (Frichs licence).	115	125	1 20
15	M. A. N.	Built in Germany.	120	150	1 40
16	FIAT	Built in Italy.	120	130	2 00
17	BERLIET	Built in France.	125	150	1 50
18	BREDA T. 10	Built in Italy.	125	145	2 00
19	A. E. C.	Built in England (licensee in Italy : Breda).	130	140	2 00
19bis	LORRAINE	Built in France.	130	152	1 50
20	CODRA-MERCEDES-BENZ	Built in France (Mercedes-Benz licence).	135	150	1 70
21	SAURER B. X. D., 4-stroke	Built in France.	140	154	1 50
22	FIAT	Built in Italy.	145	...	1 70
23	MAYBACH	Built in Germany.	150	165	1 30
24	RENAULT	Built in France.	150	165	1 50
25	C. L. M. 6 D. V. 85, 2-stroke	Built in France.	150	165	2 10
26	THOMASSEN-FRICHS	Built in Holland (Frichs licence).	150	165	1 50
27	STORK-GANZ	Built in Holland (Ganz licence).	150	165	1 50
28	GARDNER	Built in England.	153	...	1 20
29	SAURER B. X. D. S.	Built in France.	160	180	1 50
30	M. A. N. ACENOR	Built in France (M. A. N. licence).	170	180	90
31	MAYBACH	Built in Germany.	175	180	1 40

APPENDIX II.

the different Railways. (In service or under construction).

eight engine	Weight / power (n.) ratio.	Number of cylinders.	Bore	Stroke	Mean piston speed $V=\frac{CmN/r.p.m.}{30}$	Mean pressure 4-stroke cycle $382\frac{P}{D^2nVm/s}$	Fuel oil consumption per H.P./hour		Lubricating oil consumption per H.P./hour.
							Full load.	Half load.	
kgr.			millim.	millim.	m./sec.	kgr./cm².	grammes.		grammes.
...	...	6	108	152	8.6	4.7			
...	...	6	100	132	8.8	5.4			
570	6.5	3	85	120 × 2	6	5.85	205	270	5 to 6
775	9.1	6	105	165	9.35	5.7	200	240	4.5
920	10.2	6	108	152	8.1	6.1	190		
..	...	6	110	150					
...	...	6	115	150	8.25	5.85	210		
730	7.1	6	108	152	8.6	6.55	177	190	2.7
800	6.78	4	85	120 × 2	6	5.5	214	280	4
720	6.9	6	115	165	8.80	5.5	210	240	4.5
920	17.5	6	150	185	6.15	5.05	195	220	3
000	10	6	125	170	8.50	4 8	210	250	3
850	16	6	135	185	7.35	5.45	175	200	6
200	10.5	6	135	200	7.35	5.1	175	200	
025	8.5	6	140	180	8.40	4.6	182	217	8
870	7.3	6	115	160	10.7	5.4			
130	9.4	6	135	180	6.59	4.7	202	241	2
650	5.6	6	120	150	10	5.5			
641	5	6	115	142	9.8	6.2	4.5 pints.		
818	6.8	6	126	180	9	5 5	200	230	6
000	7.4	6	125	170	9.70	5.70	195-220	260	5 to 8
160	8 3	6	130	180	9	5.9	210	218	4 to 8
...	...	6	125	175	9.9	6			
900	6	6	140	175	7.6	6.4	180	200	5
150	7.7	6	140	170	8.5	5.75	174	206	1.4
600	4	6	85	105 × 2	7.3	4.5	170	206	4
300	8.7	6	145	170	8.5	5.34	190	225	
700	11.4	8	120	165	8.2	6	175	200	
770	11.6	6	140	197	7.9	6.43	177	190	2.7
160	7.7	6	134	180	9	6.3	170	...	4 to 8
200	13	6	175	220	6.6	5.35	200	196	5
100	6.3	6	140	180	8.4	6.75	213	249	5

Number.	ENGINE.	Licensee, if any.	Horse-power nominal.	Horse-power maximum.	R. p. m.
32	BURMEISTER & WAIN (2-stroke) . .	Built in Denmark.	200	230	85
33	SAURER	Built in France.	200	250	1 50
34	S. G. C.-M. A. N.	Built in France: (M. A. N. licence).	210	225	1 40
35	MAYBACH	Built in Germany.	210	220	1 40
36	RENAULT (V-type)	Built in France.	220	240	1 50
37	CARELS-GANZ	Built in Belgium (Ganz licence).	220	240	1 33
38	CORPET-FRICHS	Built in France (Frichs licence).	250	270	1 00
39	PEUGEOT C. L. M. 4 D. V. 120 (2-stroke)	Built in France.	250	275	1 50
40	ARMSTRONG-WHITWORTH-SULZER .	Built in England (Sulzer licence).	250	275	77
41	BURMEISTER & WAIN	Built in Denmark.	250	275	1 20
42	CORPET-FRICHS	Built in France (Frichs licence).	250	275	1 00
43	RENAULT (V-type)	Built in France.	265	300	1 50
44	M. A. N.-ACENOR	Built in Germany (M. A. N. licence).	280	300	1 40
45	SAURER B. Z. D. (V-type)	Built in France.	300	350	1 50
46	MERCEDES-BENZ (V-type)	Built in Germany.	300	330	1 50
47	RENAULT (V-type)	Built in France.	300	330	1 50
48	CARELS-GANZ	Built in Belgium (Ganz licence).	320	350	1 33
49	STORK-GANZ	Built in Holland (Ganz licence).	350	400	1 45
50	M. A. N.-S. G. C. M., 280/350 H.P. supercharged M. A. N. engine . . .	Built in France (M. A. N. licence). Rateau turbo-blower.	350	385	1 50
51	CARELS-GANZ	Built in Belgium (Ganz licence).	365	400	1 33
52	FRICHS (V-type)	Built in Denmark.	400	440	1 25
53	MAYBACH (V-type)	Built in Germany.	410	450	1 40
54	MERCEDES-BENZ (V-type)	Built in Germany.	450	500	1 40
55	RENAULT (V-type)	Built in France.	500	550	1 50
56	PEUGEOT C. L. M. 8 D. V. 120 (2-stroke)	Built in France.	500	550	1 50

M.A.N. = Maschinenfabrik-Augsburg-Nürnberg. — M.W.M. = Motorenwerke-Mannheim. — A.E.C. = Associated Equipment Company. — S.G.C.M. = Société Générale Construction Mécanique. — A.D.N. = Aciéries du Nord. — A.N.F. = Aciéries du Nord de la France et des Mureaux. — D.W.K. = Deutsche Werke, Kiel.

(1) Weight including turbo-blower.

(2) Weight of engine without clutch, flywheel or starter.

(3) Weight with gearbox.

eight engine	Weight / power (n.) ratio.	Number of cylinders.	Bore	Stroke	Mean piston speed $V=\frac{CmN/r.p.m.}{30}$	Mean pressure 4-stroke cycle $382\frac{P}{D^2nVm/s}$	Fuel oil consumption per H.P./hour		Lubricating oil consumption per H.P./hour.
							Full load.	Half load.	
kgr.			millim.	millim.	m./sec.	kgr./cm².	grammes.		grammes.
440	17.2	6	150	220	6.23	4.50	200	225	3
400	7	6	150	200	10	6.3	175	195	5
490	7.1	6	175	180	8	5.5	185	...	5
200	6.2	6	150	200	9.30	6.30	190	200	5
560	7.1	12	130	170	8.5	4.9	205	245	5
850	13	6	170	220	9.75	4.88	185	210	3
720	7	6	175	260	8.6	6.1	175	185	4
250	5	4	120	150 × 2	7.5	5.5	160	202	4
...	...	6	220	280	5.56				
700	6.8	6	135	220	8.8	4.96	185	210	3
100	8.4	6	185	260	8.6	5.4	185	210	4
900	7.2	12	140	170	8.4	5.1	183	214	5
900	6.9	8	175	180	8.3	5.3	183.5	214	5
000	6.6	12	130	180	9	6.3			
800	6	12	138	170	8.4	5.65	200	220	8
190	7.3	12	140	170	8.5	5.73	182	217	4
400	10.6	8	170	220	9.75	5.44	185	210	3
050	9.6	8	170	220	10.6	5.7	175	200	
020 (1)	5.8	8	175	180	9	6.06	185	215	4
000	10.95	8	170	240	10.64	5.70	190	215	4
650	10.9	12	165	200	8.33	5.6	190	200	7
030	4.7(2)	12	160	200	9.3	5.47	180	190	4
400	5.3	12	165	195	9.1	5.07	190	200	7
500 (3)	...	16	156	180	9	5.7			
900	3.8	8	180	150 × 2	7.5	5.5	under construction.		

In addition : — 135-150-H.P. Maybach G 04 engine (Fouga).

300-330-H.P. Ganz engine (builder in France: ALSTHOM).

D.W.K. (builder in France: A.N.F.).

TABLE II. — Constructional particu

Number.	ENGINE.	Nominal horse-power.	Injection.			Bearings.		Nature of connecting rod big end bearings.	
			Pumps.	Injectors.	Method of injection.	Number.	Nature.		Pisto
1	FIAT	75	Bosch.	Bosch.	Direct.	...	...		...
2	FIAT	75	...	...	...	...	...		...
3	C. L. M. 85 L. C. 3, 2-stroke	80	C.L.M.	C.L.M.	Direct.	4	Bronze. — Antifriction lined.		Cast ir
4	MERCEDES-BENZ-UNIC	85	Bosch or B.M.	Bosch or B.M.	Precombustion chamber.	7	Antifriction.	Special steel.	Light a
5	GARDNER-MIESSE	90	Bosch.	Gardner.	Direct.	7	Do.	Antifriction.	Do.
6	ARMSTRONG-WHITWORTH.	95	Bosch.	Bosch.	Direct.	7	Roller.	Antifriction.	Special a
7	BROSSEL-MIESSE	100	Bosch.	Bosch.	Air chamber.	7	Antifriction.	Antifriction.	Light a
8	GARDNER	102	Bosch.	Gardner.	Direct.	7	Antifriction.	Antifriction.	Alumin
9	C. L. M. 85 L. C. 4, 2-stroke	105	C.L.M.	C.L.M.	Direct.	5	Bronze. — Antifriction.		Cast ir
10	MERCEDES-BENZ-UNIC	105	Bosch.	Bosch.	Precombustion chamber.	7	Antifriction.	Special steel.	Light a
11	GANZ	110	Ganz.	Ganz.	Precombustion chamber.	4	Bronze. — Antifriction. Glyco or Hoyt 10 alloy.		Cast ir
12	RENAULT, 6 cylinders	110	Bosch-Lav.	Bosch-Lav.	Direct.	7	Steel. — Antifriction.		Do.
13	STORK-GANZ	115	Ganz.	Ganz.	Precombustion chamber.	7	Bronze. — Antifriction.		Do.
14	THOMASSEN-FRICHS	115	Bosch.	Bosch.	Direct.	7	Steel. — Antifriction. Glyco metal.		Alumini
15	M. A. N.	120	Bosch.	Bosch.	Direct.	7	Bronze. — Antifriction.		Cast ir
16	FIAT	120	...	...	...	...	...	...	...
17	BERLIET	125	Bosch.	Bosch.	Air injection chamber in piston.	7	Bronze. — Antifriction.	Steel. — Antifriction.	Light a
18	BREDA T. 10	125	...	...	...	...	...	...	...
19	A. E. C.	130	Bosch.	Bosch.	Precombustion chamber.	7	Bronze. — Antifriction.	Steel. — Antifriction.	Light a
19b	LORRAINE	130	Bosch.	Bosch.	Do.	7	Steel. — Antifriction		Alumini
20	CODRA-MERCEDES-BENZ	135	Bosch.	Bosch.	Direct.	7	Bronze. — Antifriction.		Light a
21	SAURER B X D (4-stroke)	140	Bosch-Lav.	Bosch-Lav.	Injection air chamber.	7	Roller.	Bronze. — Antifriction.	Do.

the engines in use on the different Railways.

Kind of metal.				Lubrication.	Starting.	Control.
onnecting rods.	Crankshaft.	Casing.	Cylinders.			
...	...	...	...	...	...	...
...	...	...	...	...	...	...
.-chr. steel.	Nick.-chr. steel.	Aluminium.	Cast iron L.	Pressure.	Electric 1 starter.	Mechanical.
cial steel.	Special steel.	Light alloy.	Special cast iron	Do.	Electric.	Do.
Do.	Do.	Do.	Cast iron.	Do.	Do.	Do.
Do.	Do.	Cast iron.	Cast iron L.	Do.	Do.	Do.
.-chr. steel.	Chr.-mol. steel.	Light alloy.	Cast iron.	Do.	Do.	Do.
Alloy.	Special steel.	Aluminium.	Cast iron L.	Do.	Do.	Do.
.-chr. steel.	Nick.-chr. steel.	Aluminium.	Cast iron L.	Do.	Do. 1 starter.	Do.
cial steel.	Chr.-mol. steel.	Light alloy.	Special cast iron	Do.	Electric.	Do.
Steel.	Special Monicro steel.	Cast iron.	Cast iron S.	Do.	Do.	Do.
.-chr. steel.	Nick.-chr. steel.	Do.	Cast iron L.	Do.	Do.	Do.
Do.	Do.	Light alloy.	Cast iron S.	Do.	Do.	Do.
Do.	Do.	Do.	Cast iron L.	Do.	Do.	Do.
Do.	Do.	Do.	Cast iron.	Do.	Do.	Do.
...	...	...	...	...	...	...
-chr. steel.	Nick.-chr. steel.	Aluminium.	Special cast iron L.	Pressure.	Electric.	Mechanical.
...	...	...	...	...	...	...
cial steel.	Special steel.	Electron alloy.	Cast iron S.	Pressure.	Electric.	Mechanical.
-chr. steel.	High-tensile steel.	Aluminium.	Special cast iron L.	Do.	Do.	Do.
cial steel.	Special steel.	Silumin or aluminium.	Grey iron L.	Do. Dry sump.	Do. Heating plug.	Do.
-chr. steel.	Nick.-chr. steel.	Cast iron.	Special very hard cast iron L.	Pressure.	Electric. 2 starters. Heating plug.	Do.

S = Cylinders machined from solid casting. — L = Cylinders with lining.

TABLE II.

Number.	ENGINE.	Nominal horse-power.	Injection.			Bearings.		Nature of connecting rod big end bearings.	Piston.
			Pumps.	Injectors.	Method of injection.	Number.	Nature.		
22	FIAT	145	Bosch.	Bosch.	Precombustion chamber.	7	...	...	...
23	MAYBACH	150	Deckel.	Deckel.	Direct.	7	Roller.	...	Light allo
24	RENAULT	150	Précision mécanique.	Précision mécanique.	Do.	7	Lead-bronze alloy.	Bi-metal lined and lead-bronze alloy.	Aluminiu alloy.
25	C. L. M. 6 D. V. 85 (2-stroke)	150	C.L.M. pump-injector.	C.L.M. pump-injector.	Do.	4	Do.	Do.	Perlitic cast iron
26	THOMASSEN-FRICHS .	150	Bosch.	Bosch.	Precombustion chamber.	7	Steel-Glyco alloy. Antifriction.		Aluminiu
27	STORK-GANZ	150	Ganz.	Ganz.	Do.	9	Ganz special.		Do.
28	GARDNER	153	Bosch.	Gardner.	Direct.	7	Antifriction.	Antifriction.	Do.
29	SAURER B. X. D. S. .	160	Bosch.	Saurer.	Do.	7	Roller.	Lead-bronze alloy.	Do.
30	M. A. N.-ACENOR . .	170	Bosch.	Bosch.	Do.	7	Bronze lined with white metal.		Do.
31	MAYBACH	175	Maybach.	Maybach.	Do.	7	Roller.		Aluminiu alloy.
32	BURMEISTER & WAIN	200	Bosch.	B. & W.	Do.	7	Bronze. — Antifriction.		Cast iron
33	SAURER	200	Bosch.	Saurer.	Do.	7	Roller.	Special bronze.	Light allo
34	S. G. C. M.-M. A. N. .	210	M.A.N.	Bosch.	Direct.	7	Bronze. — Antifriction.		Do.
35	MAYBACH	210	Deckel.	Deckel.	Do.	7	Roller.		Do.
36	RENAULT (V-type) . .	220	Précision mécanique.	Précision mécanique.	Do.	7	Steel. — Antifriction. Now white metal.		Do.
37	CARELS-GANZ	220	Ganz.	Ganz.	Precombustion chamber.	7	Bronze. — Antifriction.		Do.
38	CORPET-FRICHS . . .	220	Bosch.	Bosch.	Direct.	...	Steel. — Antifriction.	Bronze. — Antifriction.	Aluminiu
39	PEUGEOT C. L. M. 4 D. V. 120 (2-stroke) .	250	C.L.M.	C.L.M.	Do.	3	Antifriction.	Antifriction.	Perlitic cast iron
40	ARMSTRONG-WHITWORTH-SULZER.	250	Sulzer.	Bosch.	Do.	7	Do.	Do.	Aluminiu alloy.
41	BURMEISTER & WAIN	250	B. & W.	B. & W.	Do.	7	Do.	Bronze.	Special cast iron

ontinued).

Kind of metal.				Lubrication.	Starting.	Control.
Connecting rods.	Crankshaft.	Casing.	Cylinders.			
...	...	...	...	Pressure.	Electric.	Mechanical.
pecial steel.	Special steel.	Light alloy.	Cast iron S.	Do.	Electric or compressed air.	Do.
k.-chr. steel.	Nick.-chr. steel.	Cast iron.	Special cast iron L.	Do.	Electric.	Do.
Do.	Do.	Silumin.	Do.	Do.	Do.	Do.
Do.	Do.	Cast iron.	Cast iron L.	Do.	Do.	Do.
Alloy.	Special C. steel.	Do.	Do. S.	Do.	Do.	Do.
k.-chr. steel.	Nick.-chr. steel.	Do.	Do. L.	Do.	Do.	Do.
Do.	Do.	Do.	Do. L.	Do.	Do.	Do.
Nickel steel.	Nick.-chr. steel.	Cast iron.	Cast iron L.	Pressure.	Electric. Decompressor. Heating plug.	Mechanical and compressed air.
k.-chr. steel.	Nick.-chrom.-tungsten steel.	Aluminium alloy.	Cast iron S.	Pressure. Spray nozzle in front of each bearing.	Compressed air.	Mechanical.
pecial steel.	Special steel.	Light alloy.	Special cast iron S.	Pressure.	Electric.	Do.
k.-chr. steel.	Nick.-chr. steel.	Cast iron.	Cast iron.	Do.	Do.	Do.
pecial steel.	Special steel.	Steel.	Steel L.	Do.	Compressed air.	Do.
Do.	Do.	Light alloy.	Cast iron S.	Pressure. Spray nozzle in front of each bearing.	Electric.	Do.
k.-chr. steel.	Chr.-mol.-nick. steel.	Aluminium.	Cast iron L.	Pressure.	Electric. 2 starters.	Do.
pecial steel.	Special steel.	Light alloy.	Special cast iron S.	Do.	Electric.	Do.
Do.	Do.	Cast iron.	Cast iron L.	Do.	Electric generator.	Do.
k.-chr. steel.	Nick.-chr. steel.	Silumin.	Special cast iron L.	Do.	Electric or pneumatic.	Do.
Do.	Special steel.	Steel.	...	Do.	Electric.	Do.
orged steel.	Nick.-chr. steel.	Steel.	Special cast iron.	Do.	Electric.	Do.

S = Cylinders machined from solid casting. — L = Cylinders with lining.

TABLE II.

Number.	ENGINE.	Nominal horse-power.	Injection.			Bearings.		Nature of connecting rod big end bearings.	Pisto
			Pumps.	Injectors.	Method of injection.	Number.	Nature.		
42	CORPET-FRICHS . . .	250	Bosch.	Bosch.	Direct.	...	...	...	Alumin
43	RENAULT (V-type) . .	265	Précision Mécanique.	Précision Mécanique.	Do.	7	White metal.	Lead-bronze alloy.	Do.
44	M. A. N.-ACENOR . .	280	Bosch.	Bosch.	Do.	7	Bronze. — Antifriction.		Do.
45	SAURER B Z D (V-type)	300	Bosch.	Saurer.	Do.	7	Roller.	Lead-bronze alloy.	Alumin
46	MERCEDES - BENZ (V-type)	300	Bosch.	Bosch.	Precombustion chamber.	7	Bronze. — Antifriction.		Light a
47	RENAULT (V-type) . .	300	Précision Mécanique.	Précision Mécanique.	Direct.	7	Antifriction.	Bi-metal lined. White metal and lead-bronze.	Alumin alloy
48	CARELS-GANZ . . .	320	Ganz.	Ganz.	Precombustion chamber.	9	Bronze. — Antifriction.		Light a
49	STORK-GANZ	350	Ganz.	Ganz.	Do.	9	Do.		Cast ir
50	M. A. N. - S. G. C. M. 280/350 supercharged M. A. N. engine . . .	350	M. A. N.	M. A. N.	Direct.	9	Bronze. — Antifriction.	Bronze- — Antifriction.	Light a
51	CARELS-GANZ . . .	365	Ganz.	Ganz.	Precombustion chamber.	9	Bronze. — Antifriction.		Do.
52	FRICHS	400	Bosch.	Frichs.	Do.	7	Do.		Do.
53	MAYBACH (V-type) . .	410	Deckel.	Deckel.	Direct.	7	Roller.	Roller.	Alumini
54	MERCEDES - BENZ (V-type)	450	...	...	...	...	...	...	...
55	RENAULT (V-type) . .	500	Précision Mécanique.		Direct.	9	White metal.	Lead-bronze alloy.	Do.
56	PEUGEOT C. L. M. S. D. V. 120 (2-stroke) .	500	C.L.M. pump-injector.		Direct.	5	Lead-bronze.	Bi-metal. Antifriction. Lead bronze.	Perlit cast ir

Note. — M.A.N. = Maschinenfabrik-Augsburg-Nürnberg. — N.W.M. = Motoren W
Construction Mécanique. — A.D.N. = Aciéries du Nord. — A.N.F. = Aciéri

ontinued.)

Kind of metal.				Lubrication.	Starting.	Control.
Connecting rods.	Crankshaft.	Casing.	Cylinders.			
pecial steel.	Special steel.	Cast iron.	Cast iron L.	Pressure.	Electric.	Mechanical.
ressed steel.	Do.	Aluminium.	Do.	Do.	Do.	Do.
pecial steel.	Do.	Cast iron.	Do.	Do.	Do.	Do.
k.-chr. steel.	Nick.-chr. steel.	Cast iron.	Cast iron L.	Do.	Do.	Do.
pecial steel.	Special steel.	Silumin.	Grey iron.	Pressure. Dry sump.	Electric. Heating plug. Decompressor.	Do.
k.-chr. steel.	Nick.-chr. steel.	Aluminium alloy.	Special cast iron L.	Pressure.	Electric.	Do.
pecial steel.	Special steel.	Light alloy.	Special cast iron S.	Do.	Do.	Do.
k.-chr. steel.	Nick.-chr. steel.	Do.	Cast iron S.	Do.	Do.	Hydraulic.
ecial steel.	Do.	Steel.	Steel L.	Do.	Do.	Mechanical.
Do.	Do.	Light alloy.	Special cast iron S.	Do.	Do.	Do.
Do.	Do.	Do.	Cast iron L.	Do.	Do.	Do.
k.-chr. steel.	Nick.-chr. steel.	Do.	Cast iron S.	Pressure. Spray nozzle in front of each bearing.	Electric generator. Electric or compressed air. Heating plug.	Hydraulic.
...	...	...	...	...	...	...
Do	Special steel.	Aluminium.	Cast iron S.	Pressure.	Electric.	Mechanical.
k.-chr. steel.	Nick.-chr. steel.	Silumin.	Perlitic cast iron.	Do.	Electric or pneumatic.	Do.

S = Cylinders machined from solid casting. — L = Cylinders with lining.
nheim. — A.E.C. = Associated Equipment Company. — S.G.C.M. = Société Générale
l de la France et des Mureaux. — D.W.K. = Deutsche Werke, Kiel.

[621. 392 & 625. 143]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

13th SESSION (PARIS, 1937).

QUESTION II.

Use of welding :

1. to obtain extra-long rails ;
2. in manufacturing and repairing points and crossings.

a) **Results obtained by using extra-long rails. Methods used to ensure safe expansion of the rails, and anchoring of the track.**

b) **Technical and financial results shown by welding points and crossings.**

SUPPLEMENT TO REPORT (*)

by J. RIDET,

Ingénieur des Ponts et Chaussées, Ingénieur en chef adjoint de la Voie et des Travaux ;
Compagnie des Chemins de fer de l'Est (France).

NOTE

summing up the information supplied by the Italian State Railways.

The *Italian State Railways* seem to be greatly interested in a process whereby rails can be welded in position on lines in service without removing them and without restricting the train speeds.

Complex joints. — Tests and results. — Electric arc-welded complex joints would meet these conditions. They would be cheaper than thermit-welded joints as the following figures show :

Complex joints : 30, 60 and 85 lires according to type;

Thermit welded joints : 90 lires.

Complex joints, however, require *expert welders* to make them. About 500 joints of five different types were put into service in 1933. In all of them the rail heads, with or without a V-shaped notch to facilitate welding, were welded together.

The joints with a V-shaped notch in the rail heads have stood up in traffic, whereas cracks developed in the others.

In spite of this, a further 160 joints were welded in 1934, none of which had the rail notched before welding.

The Italian State Rys. report that the use of coated electrodes in place of bare ones is all that is needed to prevent the development of cracks.

In the type of joint adopted, the rail heads and flanges are welded, the two ends being set 15 mm. (5/8″) apart and supported by a bearing plate acting as a bridge between the two joint sleepers.

(*) See *Bulletin of the Railway Congress*, January 1937, p. 171/99.

The flanges of the rails are welded to this plate as well.

One thousand of these joints are in use in tunnels. The Railway reports they are satisfactory, but that the time they have been in use is too short for any final opinion to be expressed.

Length of welded rails. — Outside tunnels the length of the rails is 36 m. (118′), obtained by welding two 18-m. (59′) rails together. In tunnels, rails up to 90 m. (295′) long are in use.

Expansion. — The limiting rail temperatures recorded are -15° C., (5° F.) and + 60° C. (140° F.).

Rules for laying the rails prescribe the gap to be left at different temperatures, according to the method of rail fastening used.

The *Italian State Rys.* use two types of fastenings :

(a) *direct :* the rail rests on a bearing plate and is fastened to the sleeper by three coach screws passing through the plate, the heads of the screws bearing on the rail foot.

(b) *indirect :* the rail is fastened to a bearing plate by means of two clips which are bolted to the bearing plate and bear on the rail foot. The bearing plate is fastened to the sleeper by four coach screws.

In the case of rails of ordinary length (6 to 18 m. = 19′ 8″ to 39′) with direct fastenings, the rules for laying the rails provide for free expansion between — 10° and + 50° C. (14 and 122° F.). These rules were based on rather high expansion constants (12 to 16.6 × 10^{-6} according to the rail length) so that with the gaps as specified in the rules, the rails can probably expand freely between — 20° and + 60° C. (—4 and + 140° F.).

In the case of rails with indirect fastenings, according to the rules for laying rails, the ends will be in compression at a temperature of 26 to 33° C. (79 to 91° F.) according to the climatic conditions where the rails are used.

The *Italian State Rys.* think part of the expansion can be absorbed by the restraining forces due to friction between rails and sleepers, and between sleepers and ballast.

Exacts measurements of the expansion of 36 and even 72-m. (118′ and 236′) rails showed that the variation in length of these rails were much less than the calculated value for free expansion. For this reason the rules for laying rails applied to 36-m. (118′) rails with indirect fastenings specify gaps but little wider than those for 18-m. (39′) rails. For example at 15° C. (59° F.) the specified gap is :

8 mm (5/16″) for 18-m. (59′) rails and 10 mm. (3/8) for 36-m. (118′) rails.

At 26° C. (79° F.) the gap should be :

2 mm. (5/64″) for 18-m. (59′) rails and 2 mm. (5/64″) for 36-m. (118′) rails.

No particular arrangement other than the use of indirect fastenings appears to be used to prevent transverse deformation of the track.